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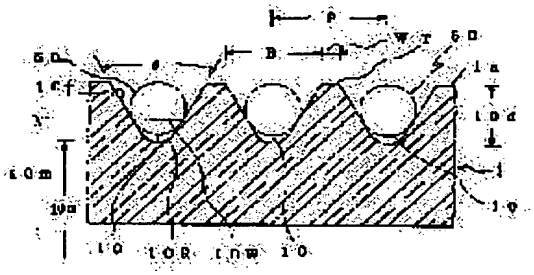
(54) CERAMICS-MADE MULTIGROOVE ROLLER FOR WIRE SAW

(57)Abstract:
PROBLEM TO BE SOLVED: To prevent generation of chipping at groove working time, by forming a groove forming part of a ceramics-made multigroove roller by ceramics of a prescribed % or more alumina content.
SOLUTION: A ceramics-made multigroove roller 1 for a wire saw is formed into a hollow cylindrical shape by ceramics. As this ceramics, an alumina content is 90% or more, for instance, ceramics of 97% purity or the like is used. In a surface 1a of the multigroove roller 1, a plurality of wire grooves 10 are provided with a space apart in a center core axial direction. Deflection in a radial direction of the wire groove 10 relating to the center core axis of the multigroove roller 1 is 20μm or less, deflection in an axial direction of the wire groove 10 relating to the center core axis of the multigroove roller 1 is 20μm or less.



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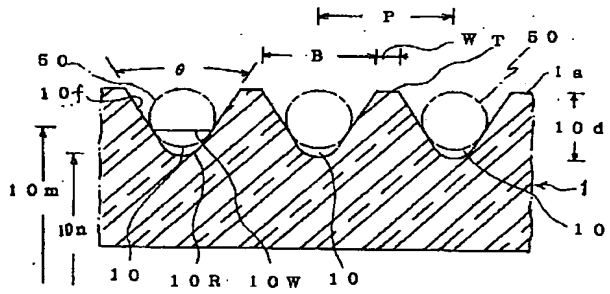
(54)【発明の名称】　ワイヤーソーのセラミックス製多溝ローラ

(57)【要約】
【課題】溝加工時にチッピングが発生しないようにするとともに、ワイヤー溝の深さを従来例のそれより浅くし、且、脱線、断線が生じないようにする。
【解決手段】表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分を、アルミナ含有量が９０％以上のセラミックスで形成する。



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【特許請求の範囲】

【請求項１】　表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、アルミナ含有量が９０％以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項２】　表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、曲げ強度３５００ｋｇ／ｃｍ²以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項３】　表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの２本以上がセラミックス製ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラのワイヤー溝の深さが、５０～５００μｍであり、
該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが２０μｍ以下であり、
該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが２０μｍ以下であること、
を特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項４】　表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの２本以上がセラミックス製ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラが、アルミナの含有量が９０％以上のセラミックスで形成され、
該多溝ローラのワイヤー溝の深さが、５０～５００μｍであり、
該多溝ローラ溝の中芯軸に対するワイヤー溝のラジアル方向の振れが２０μｍ以下であり、
該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが２０μｍ以下であること、
を特徴とするワイヤーソーのセラミックス製多溝ローラ。

【請求項５】　表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの２本以上がセラミックス製ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラが、曲げ強度３５００ｋｇ／ｃｍ²以上のセラミックスで形成され、
該多溝ローラのワイヤー溝の深さが、５０～５００μｍであり、
該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが２０μｍ以下であり、
該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが２０μｍ以下であること、
を特徴とするワイヤーソーのセラミックス製多溝ローラ。

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【請求項６】　一本のセラミックス製多溝ローラのワイヤー溝の直径のばらつきが、３０μｍ以下であることを特徴とする請求項１、２、３、４、又は、５記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項７】　一本のセラミックス製多溝ローラの溝ピッチの誤差の累積が、３０μｍ以下であることを特徴とする請求項１、２、３、４、又は、５記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項８】　一本のセラミックス製多溝ローラのワイヤー溝の直径のばらつきが、３０μｍ以下であり、該ワイヤー溝のピッチの誤差の累積が、３０μｍ以下であることを特徴とする請求項１、２、３、４、又は、５記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項９】　被加工物に対向する２本のセラミックス製多溝ローラの、各々の多溝ローラのワイヤー溝の直径のばらつきの合計が６０μｍ以下であることを特徴とする請求項３、４、又は、５記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項１０】　被加工物に対向する２本のセラミックス製多溝ローラの、相対するワイヤー溝の溝ピッチの相互累積誤差が６０μｍ以下であることを特徴とする請求項３、４、又は、５記載のワイヤーソーのセラミックス製多溝ローラ。

【請求項１１】　被加工物に対向する２本のセラミックス製多溝ローラの、各々の多溝ローラのワイヤー溝の直径のばらつきの合計が６０μｍ以下であり、かつ、相対する該ワイヤー溝の溝ピッチの相互累積誤差が６０μｍ以下であることを特徴とする請求項３、４、又は、５記載のワイヤーソーのセラミックス製多溝ローラ。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】この発明は、シリコン、磁性体、水晶等を切断するワイヤーソーに関するもので、更に述べると、ワイヤーソーのセラミックス製多溝ローラに関するものである。

【０００２】

【従来の技術】ワイヤーソーは、ワイヤーを張設した複数の多溝ローラを備えており、該多溝ローラを回転させて該ワイヤーを直線運動させることにより、シリコン、磁性体、水晶、セラミックス等の被加工物（ワーク）を切断する。

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【０００３】従来の多溝ローラは、樹脂例えばナイロンで形成され、その表面には複数のワイヤー溝が設けられている。このワイヤー溝の深さは、通常０．５～１ｍｍの範囲で形成されるが、その材質が柔軟であり、かつ、加工性も良いので、ワイヤー溝の加工作業が容易である反面、磨耗し易いので耐久性において問題がある。そこで、近年、前記問題を解決するため、セラミックス製ローラが使用されている（特開昭６３－２３７８６３号公報参照）。

【０００４】

【発明が解決しようとする課題】セラミックスの硬度は、ナイロンに比べ著しく高く、例えば、６６ナイロンのロックウェル硬度は、Ｒ１１２であるが、アルミナの含有量が９７％のセラミックスはその硬度が高過ぎるので、ロックウェル硬度での測定は不可能である。そこで、該セラミックスのビッカース硬度を測定したところ、Ｈｖ１４００であった。このＨｖ１４００は高過ぎてロックウェル硬度との比較はできない。

【０００５】多溝ローラのワイヤー溝がナイロンで形成されている場合は、ワイヤー溝の精度誤差をワイヤー溝が変形若しくは、ワイヤーが伸縮して補っていた。しかし、該ワイヤー溝がセラミックスで形成されている場合、ワイヤー溝が変形しないため、ワイヤー溝の精度誤差のすべてをワイヤーが伸縮することのみによって補わなければならない。従って、ワイヤー溝がセラミックスで形成される場合、ワイヤーにかかるストレスがナイロンでワイヤー溝を形成された場合よりはるかに多い。

【０００６】上記事情より、ワイヤーソーのセラミックス製多溝ローラは、ナイロン製多溝ローラよりはるかに高い精度でワイヤー溝を形成しなければならない。

【０００７】ナイロン製多溝ローラは、ＮＣ旋盤を用いバイトによる切削によりワイヤー溝を加工していた。しかし、セラミックス製ローラのワイヤー溝を加工する場合は、前述の様にセラミックスは極めて硬度が高い為、例えばＮＣ円筒研削盤を用いダイヤモンド砥石による研削加工になる。そのため、従来例に比べ加工に要する時間が著しく長くなるとともに、加工費用も嵩むようになる。

【０００８】その上、砥石先端の磨耗が激しく、一本のセラミックス製多溝ローラの溝加工の途中で砥石を交換しなければならないことがある。しかし、該砥石を交換すると、ワイヤー溝と該砥石との位置関係を交換直前の状態に精確に合わせることが困難であり、結果ワイヤー溝の溝ピッチの誤差要因となる。そのため、ワイヤー溝を設計通りに精確に形成することができず、脱線や、断線の原因となることがある。

【０００９】そこで、ワイヤー溝の深さを従来のナイロン製多溝ローラより浅くすることにより、前記問題を解決することが考えられる。しかし、ワイヤー溝を浅くするとワイヤーの脱線が発生し易くなり、ワイヤーが脱線

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してしまうと切断中の被加工物（ワーク）を駄目にしてしまう。

【００１０】又、前述の様にセラミックス製多溝ローラは変形がほとんど無いので、加工精度向上及び加工速度向上の為、ナイロン製多溝ローラよりワイヤーに高い張力を掛けて使用されることが多い。更に、この多溝ローラは被加工物（ワーク）の削り量を減らす為、及び一度に多くの数量を切断する為に、細い径のワイヤー、例えば、直径０．１ｍｍのピアノ線が使用される。そのため、ワイヤーに設計値よりわずかでも多い荷重がワイヤーにかかると断線してしまう。

【００１１】更に、近年では被加工物（ワーク）の多様化が進み、それに伴い要求されるワイヤー溝の溝ピッチも多種にわたってきている。特に、被加工物を極薄肉に加工する場合には、溝ピッチ０．２ｍｍ以下が要求されるが、この溝ピッチが小さくなると、それに比例して、溝間山の山頂山幅も当然小さくなる。しかし、セラミックス製多溝ローラは硬脆性材料であるため、山頂山幅を小さくすればワイヤー溝加工時に溝間山にチッピングが発生する。そのため、溝間山を設計通りに形成することが困難となる。溝間山が設計通りに形成出来ない場合には、ワイヤーの脱線、断線が発生したり被加工物（ワーク）の加工精度にも悪影響を及ぼす。

【００１２】この発明は、上記事情に鑑み、溝加工時にチッピングが発生しないようにすることである。他の目的は、ワイヤー溝の深さを従来例のそれより浅くするとともに、脱線、断線が生じないようにすることを目的とする。

【００１３】

【課題を解決するための手段】この発明は、表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、アルミナの含有量が９０％以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ、である。この発明は、表面に複数のワイヤー溝と溝間山とを有するワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラの溝形成部分が、曲げ強度３５００ｋｇ／ｃｍ^{2}以上のセラミックスで形成されていることを特徴とするワイヤーソーのセラミックス製多溝ローラ、ある。

【００１４】この発明は、表面に複数のワイヤー溝を有し、かつ、互いに平行に配設される複数の多溝ローラと、該複数の多溝ローラのまわりに捲回され、かつ、ワイヤー溝により案内されるワイヤーと、を備え、該多溝ローラの２本以上がセラミックス製多溝ローラで構成されるワイヤーソーのセラミックス製多溝ローラにおいて；該セラミックス製多溝ローラのワイヤー溝の深さが、５０～５００μｍであり、該多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れが２０μｍ以下

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であり、該多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れが２０μｍ以下であること、を特徴とするワイヤーソーのセラミックス製多溝ローラ、である。この発明において、一本のセラミックス製多溝ローラのワイヤー溝の直径のばらつきが、３０μｍ以下であり、該ワイヤー溝のピッチの誤差の累積が３０μｍ以下であるように形成したり、又、被加工物に対向する２本のセラミックス製多溝ローラの、各々の多溝ローラのワイヤー溝の直径のばらつきの合計が６０μｍ以下であり、該ワイヤー溝の相対する溝ピッチの相互累積誤差が６０μｍ以下であるように形成してもよい。

【００１５】

【発明の実施の形態】本発明者は、溝間山の山頂山幅を狭く、例えば、４０μｍ以下にすると、チッピングが発生するのは、材質に問題があるのではないか、と考え、アルミナ成分の含有量を変えながらチッピングが発生するか否かを実験した。その結果、アルミナの含有量が９０％以上、又は、曲げ強度が３５００ｋｇ／ｃｍ^{2}以上になると、溝間山の山頂山幅が狭くなっても、例えば、４０μｍとなってもチッピングが発生しないことがわかった。そこで、セラミックス製多溝ローラの材質としてアルミナの含有量が９０％以上のセラミックス又は曲げ強度３５００ｋｇ／ｃｍ^{2}以上のセラミックスを採用することとした。

【００１６】本発明者は、セラミックス製多溝ローラの場合にワイヤーが脱線したり、断線したりし易いのは、ワイヤー溝がナイロン製多溝ローラに比べ、変形量が極く少ないためであると考えた。即ち、ナイロン製多溝ローラでは、ワイヤー溝が変形若しくは、ワイヤーが伸張することによって多溝ローラのワイヤー溝の振れ等の精度を補っているが、セラミックス製多溝ローラでは、ワイヤー溝の変形による調整はほとんど無く、ワイヤーのみですべての精度を補っているのである。

【００１７】ワイヤーの脱線、断線を防止するには、設計値に対して誤差が無い様に精確にワイヤー溝を形成すれば良いが、そのように形成することは、極めて困難である。そこで、本発明者は、脱線、断線の原因を追求したところ、その主なる原因は、多溝ローラの中芯軸に対するワイヤー溝のアキシャル方向の振れ（以下アキシャル方向の振れ、という）と多溝ローラの中芯軸に対するワイヤー溝のラジアル方向の振れ（以下ラジアル方向の振れ、という）にあることがわかった。

【００１８】そこで、これらの振れが生じても脱線、断線しない範囲、即ち、振れの許容範囲を求めたところ、ワイヤー溝の深さが、５０～５００μｍのセラミックス製多溝ローラのワイヤー溝では、アキシャル方向の振れが２０μｍ以下、ラジアル方向の振れが２０μｍ以下、であることがわかった。

【００１９】更に次の条件を満たすと、より好ましいことがわかった。

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（１）一本の多溝ローラのワイヤー溝の径、即ち、ワイヤー溝の溝底の径及びワイヤーがワイヤー溝の両側壁に当接する点を結ぶ直線部の径、のばらつきが３０μｍ以下であること。

（２）被加工物に対向する２本のセラミックス製多溝ローラの、該各多溝ローラのワイヤー溝の直径、即ち、ワイヤー溝の溝底の径及びワイヤーがワイヤー溝の両側壁に当接する点を結ぶ直線部の径、のばらつきの合計が６０μｍ以下であること。

【００２０】（３）一本の多溝ローラのワイヤー溝の溝ピッチ累積誤差が３０μｍ以下であること。

（４）被加工物に対向する２本のセラミックス製多溝ローラの相対するワイヤー溝の溝ピッチの累積誤差が６０μｍ以下であること。そこで、以上の許容範囲内のワイヤー溝を加工条件として採用することにした。

【００２１】なお、セラミックス製多溝ローラのワイヤー溝はワイヤーが嵌着出来る様に形成されなければならないが、その形状、大きさ、数等は必要に応じて適宜選択される。例えば、ワイヤーがワイヤー溝の溝底に当接する様な形状にしたり、又、ワイヤーがワイヤー溝の両側壁に当接する様な形状等、に形成される。

【００２２】又、多溝ローラを形成するセラミックスとして、純度９０％以上、即ちアルミナの含有量が９０％以上のセラミックス、ジルコニア、炭化珪素、窒化珪素等が用いられる。

【００２３】

【実施例１】この発明の第一実施例を図１～図６により説明する。ワイヤーソーのセラミックス製多溝ローラ１はセラミックスにより中空円筒状に形成されており、その外径Ｄは、４０ｍｍ、内径１ｄは２０ｍｍ、長さＬｎは１００ｍｍ、である。このセラミックスとして、アルミナの含有量が９０％以上、例えば、純度９７％のセラミックス等が用いられる。

【００２４】該多溝ローラ１の中空部２には、補強部材５が設けられている。この補強部材５は、該多溝ローラ１と一体に形成された同芯状の円盤形状である。この円盤形状の補強部材５の厚さ５ｔは、多溝ローラ１の肉厚１ｔ＝１０ｍｍと同一厚さ、であり、両者の肉厚比１ｔ／５ｔは１であるが、この肉厚比１ｔ／５ｔは多溝ローラの剛性等を考慮して選択される。

【００２５】円盤形状の補強部材５は、１個設けられているが、この配設個数も該多溝ローラ１の長さＬｎ等を考慮し、適宜選択され、例えば、中芯軸Ｃ方向に等間隔に３つの円盤形状の補強部材５が配設される場合や、逆に補強部材５を省略することもある。

【００２６】円盤形状の補強部材５には、５個の軽量化用穴６が設けられており、この軽量化用穴６により補強部材５の軽量化を図る。この軽量化用穴６の位置、個数、形状等は、要求される多溝ローラ１の剛性等を考慮して適宜選択され、例えば、軽量化用穴６が貫通してい

なかったり、８個の多角形状の軽量化用穴６が採用されたりする。

【００２７】該多溝ローラの表面１ａには、中芯軸Ｃ方向に間隔をおいて複数のワイヤー溝１０が設けられている。このワイヤー溝１０は、図示しないＮＣ円筒研削盤により設計図に基づいて精確に加工される。例えば、そのワイヤー溝深さ１０ｄ＝０．１２ｍｍ、溝角度θ＝６０°、溝ピッチＰ＝０．２４ｍｍ、溝幅＝０．２ｍｍ、溝間山の山頂山幅Ｗ＝０．０４ｍｍ、溝数２９６、に形成される。

【００２８】該多溝ローラ１の両端１ｅには円盤状に形成された金属製支持部材３０が設けられている。該金属製支持部材３０の外面３０ａの中央部には、軸部３１が配設され、又、その内面３０ｂの外周部には、嵌合部３３が形成されている。この嵌合部３３は多溝ローラ１の端部１ｅに嵌合されているが、該両部３３、１ｅはエポキシ樹脂等の接着剤３５により接着されている。

【００２９】この両部３３、１ｅの接合長さＬ３３は多溝ローラ１の長さＬｎより極めて短いので、ワイヤーソーの装置を運転することにより温度変化が生じ両者が伸縮して変位しても両部の接合状態は維持される。尚、この金属製支持部材３０は、一般に鉄、鋼などが用いられるが、セラミックスの熱膨張率と同一又は近似な熱膨張率の材料で円盤形状に形成されるのが好ましく、例えば、この材料として、チタンやチタン合金等が用いられる。

【００３０】次にワイヤーソーの作動について説明する。図示しないワイヤーソーの多溝ローラ取付部位に多溝ローラ１の軸部３１を装着する。この装着された複数の多溝ローラ１を囲む様にしながら一本の直径０．１２ｍｍのワイヤー５０を相対するワイヤー溝１０に巻き付け、多数のワイヤー列５０Ａを形成する。この時、一本の多溝ローラのワイヤー溝の直径、即ち、ワイヤー溝底１０Ｒの直径１０ｎ、ワイヤー溝の両側の側壁１０ｆとワイヤーとが接触する当接点を結ぶ直線部１０Ｗの直径１０ｍのばらつきが３０μｍ以下であり、該ワイヤー溝の溝ピッチＰの累積誤差が３０μｍ以下、である。

【００３１】又、一装置内で使用されている被加工物に対向する２本のセラミックス製多溝ローラの各々の多溝ローラのワイヤー溝の直径のばらつきの合計、即ち、各セラミックス製多溝ローラのワイヤー溝底１０Ｒの直径１０ｎ、ワイヤー溝の両側の側壁１０ｆとワイヤーとが接触する当接点を結ぶ直線部１０Ｗの直径１０ｍのばらつきの合計が６０μｍ以下であり、相対するセラミックス製多溝ローラの相対する溝ピッチＰの相互誤差の累積が６０μｍ以下である。

【００３２】多溝ローラを反転往復、若しくは一方向回転運動することによりワイヤー列５０Ａを矢印Ａ５０の様に往復若しくは、一方向直線運動させる。この時のセラミックス製多溝ローラ１の中芯軸Ｃに対するワイヤー溝１０のラジアル方向ＡＲの振れは２０μｍ以下であり、又、該セラミックス製多溝ローラ１の中芯軸Ｃに対するワイヤー溝１０のアキシャル方向ＡＸの振れが２０μｍ以下、である。

【００３３】このワイヤー５０に被加工物（ワーク）ＢＷを押し当てるとともに、図示しない吐出ノズルから研磨材を吐出し、両者間に研磨剤を介在せしめながら切断を行う。

【００３４】このセラミックス製多溝ローラ１の回転に伴い、慣性力が発生するが、この多溝ローラ１は、従来例に比べ極めて軽量なので、その慣性力も極めて小さいものになる。

【００３５】又、ワイヤーソーの運転時において、温度変化が生じ、該セラミックス製多溝ローラ１と金属製支持部材３０とが共に伸縮することがあるが、両者１、３０を熱膨張率が略等しい材料にすると、略同一割合で同時に伸縮する為、接着部位の剥離等が発生しないので、好ましい。

【００３６】上記ワイヤーソーの運転時においてワイヤー溝の振れが発生するが、該多溝ローラ１の中芯軸Ｃに対するワイヤー溝１０のラジアル方向ＡＲの振れは２０μｍ以下であり、又、該多溝ローラ１の中芯軸Ｃに対するワイヤー溝１０のアキシャル方向ＡＸの振れが２０μｍ以下である。

【００３７】上記セラミックス製多溝ローラを使用したワイヤーソーで直径が８インチのシリコンの切断加工を行った結果、ワイヤーの脱線、断線等が発生せず、又セラミックス部と金属製支持部材の剥離等もみられず、被加工物であるウエハーの寸法精度は５μｍ以上を維持して加工することができた。

【００３８】本実施例におけるセラミックス製多溝ローラ１の中芯軸Ｃに対するラジアル方向ＡＲのワイヤー溝の振れの許容範囲は、計算によっても求められる。この振れの許容範囲は、脱線が発生する振れの限界を示すものである。

【００３９】次に、本実施例の脱線計算図である図６により前記許容範囲を計算する。ワイヤーソーのワイヤーの脱線は様々な原因が合わさって発生するが、その脱線の経過は次の通りである。

（１）隣のワイヤー溝から走行してきたワイヤーはワイヤー溝に対して斜めに入ってくるため、図６のＢ付近の様に該ワイヤー溝の側壁１０ｆにワイヤー５０が接触する。

【００４０】（２）該ワイヤーはセラミックス製多溝ローラ１の回転及び側壁１０ｆの外周方向への力を受ける。

（３）セラミックス製多溝ローラのワイヤー溝のラジアル方向ＡＲの振れにより二本の対向する多溝ローラ間の中芯軸Ｃ間隔Ｌが短くなり、ワイヤー５０が緩んで脱線する。

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【００４１】この脱線時を示す図６から次の関係式が求められる。

$y+z=L+l+\Delta x$ （１）

$\cos\theta=r/(r+t)$ （２）

$l=2\pi r\times\theta/360$ （３）

$r^2+z^2=(r+t)^2$ （４）

$(L-\Delta x)^2+t^2=y^2$ （５）

【００４２】上記式において、Ｌ：多溝ローラ間の理論的に精確な距離、ｌ：円弧の長さ、ｒ：多溝ローラとワイヤーの接触部分の半径、ｔ：脱線開始時のワイヤー移動距離、Δｘ：多溝ローラのワイヤー溝の振れ量、をそ＊

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＊れぞれ示す。

【００４３】上記式（１）～（５）より、脱線の発生する多溝ローラのワイヤー溝の振れが求められる。次にその計算例を示す。

計算例１：脱線が発生する多溝ローラのワイヤー溝の振れ量Δｘを求めるための条件。

Ｌ＝１００　単位［ｍｍ］

ｒ＝　２０

ｔ＝０．４

【００４４】

（２）式より　$COS\theta=20/(20+0.4)=0.98039$

$\theta=COS^{-1}0.98039=11.365°$

（３）式より　$l=2\pi\times20\times11.365/360=3.9671$

（４）式より　$Z=\sqrt{((r+t)^2-r^2)}$

$=\sqrt{((20+0.4)^2-20^2)}$

$=4.0200$

【００４５】（１）、（５）式より

$(L-\Delta x)^2+t^2=(L+l+\Delta x-z)^2$

$\therefore\ (100-\Delta x)^2+0.4^2$

$=(100+3.967-4.0200+\Delta x)^2$

$10000-200\Delta x+\Delta x^2+0.16$

$=9989.4028+199.894\Delta x+2\Delta x^2$

$\therefore\ \Delta x^2+399.894\Delta x-10.757=0$

$\Delta x=26.9[\mu m]$

【００４６】計算例２：脱線が発生する多溝ローラのワイヤー溝の振れ量Δｘを求めるための条件。

Ｌ＝１００　単位［ｍｍ］

ｒ＝　３０

ｔ＝０．４

計算例１と同様に計算して

Δｘ＝２１．７［μｍ］

【００４７】上記計算例によりセラミックス製多溝ローラのワイヤー溝の振れ量Δｘを求めたが、セラミックス製多溝ローラの中芯軸Ｃに対するワイヤー溝のラジアル方向ＡＲの振れは、前記計算例１、２より２０μｍ以下になる様に製作することが望ましい。

【００４８】

【実施例２】この発明の第２実施例を図７により説明する。この実施例と第１実施例との相違点は、次の通りである。ワイヤー溝１０の断面形状において、底面の溝角度θ1＝９０°、側壁の溝角度θ2＝１０°、溝幅Ｂ＝０．３ｍｍ、溝間山の山頂山幅Ｗ＝０．１ｍｍ、溝深さ１０ｄ＝０．３ｍｍ、溝ピッチ＝０．４ｍｍであることである。

【００４９】

【実施例３】この発明の第３実施例を図８により説明する。セラミックス製多溝ローラのアルミナ含有量（純度％）又は曲げ強度と加工時にチッピングが発生しない溝間山の山頂山幅との関係を知る為に次の実験をした。図８に示す様に、アルミナ含有量の異なるセラミックス製多溝ローラ１に同一形状のワイヤー溝１０をピッチ０．４ｍｍから１μｍづつ狭めていき該各多溝ローラにおいてチッピングの発生が見られる最大山頂山幅Ｗを調べた。尚加工条件は次の通りである。

【００５０】加工機：ＮＣ円筒研削盤

砥石：ダイヤモンド砥石、粒度＃４００

加工ワーク（アルミナ材）：直径６５ｍｍ、長さ１００ｍｍ

回転数２００ｒｐｍ

加工溝形状：溝角度θ＝６０°、溝深さ１０ｄ＝０．１５ｍｍ

実験の結果を表１及び図９、図１０に示す。

【００５１】

【表１】

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アルミナ純度（％）	チッピング発生最大山幅（μｍ） 実験１	実験２	実験３	平均	曲げ強度（ｋｇ／ｃ㎡）
７５	９９	９３	８４	９２．０	２３００
８８	８２	７２	７３	７５．６	２７００
９０	３１	３４	３１	３２．０	３５００
９７	４４	４５	３２	４０．３	４１００
９９．５	１８	１３	１９	１６．７	３６００

【００５２】図９はアルミナ含有量即ちアルミナ純度（横軸％）とチッピング発生山頂山幅（縦軸μｍ）との関係を示す図である。この図において、丸印は第１回目の実験結果、正方形印は第２回目の実験結果、三角印は第３回目の実験結果、×印は平均を示す。

【００５３】図１０はアルミナ純度（横軸％）とチッピング発生山頂山幅（左縦軸μｍ）と曲げ強度（右縦軸ｋｇ／ｃｍ^2）との関係を示す図である。この図において正方形印は山頂山幅、丸印は曲げ強度を示す。

【００５４】表１及び図９、図１０から材質がアルミナ含有量７５％、８８％のもの又は曲げ強度２３００ｋｇ／ｃｍ^2、２７００ｋｇ／ｃｍ^{2}のものの山頂山幅は、アルミナ純度９０％、９２％、９７％、９９．５％のもの、又は、曲げ強度３５００ｋｇ／ｃｍ^2、４１００ｋｇ／ｃｍ^2、３６００ｋｇ／ｃｍ^{2}のものの山頂山幅に比べ２、３倍以上広いことがわかった。即ち、山頂山幅Ｗはアルミナの含有量が９０％以上又は曲げ強度３５００ｋｇ／ｃｍ^{2}以上になると、極端に狭くしてもチッピングが発生しないことがわかった。

【００５５】

【実施例４】この発明の第４実施例を説明する。純度９７％のアルミナからなる直径６０ｍｍのセラミックス製多溝ローラに溝ピッチＰ＝０．３ｍｍ、溝間山の山頂山幅Ｗ＝５０μｍのワイヤー溝をダイヤモンドホイールを用いて加工したが、チッピングは発生しなかった。この多溝ローラをワイヤーソーに装着し、水晶の極薄切断加工を行ったところ、厚さ精度は５μｍ以上と精密な切断が行われた。ワイヤー溝は、ワイヤーに付着した砥粒により微かづつ研磨され磨耗するが、３００時間という長時間にわたり上記精度を保って切断加工を行うことができた。

【００５６】

【実施例５】この発明の第５実施例を説明する。純度９７％のアルミナからなる上記同様の仕様のセラミックス製多溝ローラにワイヤー溝ピッチＰ＝０．２５ｍｍ、溝間山の山頂山幅Ｗ＝４０μｍのワイヤー溝をダイヤモンドホイールを用いて加工したが、実施例４と同様にチッピングは発生しなかった。この多溝ローラをワイヤーソーに装着し磁性体の極薄切断加工を行ったところ、ワークの厚さ精度は上記同様５μｍ以上を維持することが出きた。

【００５７】

【実施例６】この発明の第６実施例を図１１により説明する。ローラは必ずしも全部を前記セラミックスで形成する必要はなく、溝形成部分が前記セラミックスで形成されておれば足りる。その具体例は、次の通りである。

（１）図１１（Ａ）に示す様に、金属製パイプ８０に、ワイヤー溝１０の付いた前記セラミックス製の円筒状外周部８１を設ける。この金属パイプ８０の両端には装着部８２が設けられ、又、一端には外周部８１を固定するための止め部材８３が設けられている。

【００５８】（２）図１１（Ｂ）に示す様に、金属製パイプ９０にワイヤー溝１０の付いた前記セラミックス製の円筒状外周部９１を設ける。一端９０ａには、突状環部９２が形成され、中空部９３には、穴９４のあいた補強円板９５が設けられ、その他端９０ｂには、該外周部９１を固定する蓋体９６が固定される。

【００５９】

【実施例７】この発明の第７実施例を図１２により説明する。この実施例も前記第６実施例と同様に溝形成部分が前記セラミックスで形成されて場合である。

（３）図１２（Ａ）に示す様に、金属製パイプ１００にワイヤー溝１０の付いた前記セラミックス製の円筒状外周部１０１を設ける。この金属製パイプ１００の一端２１００ａには、ベアリング軸部１０５が設けられ、他端１００ｂには円錐台状の軸受部１０６が形成されてい

る。該パイプ１００の外周には円筒状凹部１０７が形成され、この凹部１０７に前記円筒状外周部１０１が嵌着され固定されている。

【００６０】（４）図１２（Ｂ）に示す様に、金属製パイプ１１０に、ワイヤー溝１０の付いた前記セラミックス製の円筒状外周部１１１を設ける。この金属製パイプ１１０の両端には、円錐台状の軸受部１１５、１１６が設けられている。該パイプ１１０の外周には、円筒状凹部１１７が形成され、該凹部１１７に前記円筒状外周部１１１が嵌着され固定される。

【００６１】

【実施例８】この発明の第７実施例を図１３により説明する。前記実施例では、溝形成部分を前記セラミックスで形成したが、このセラミックス製多溝ローラ全体を前記セラミックスで形成することもできる。その具体例は、次の通りである。

（１）図１３（Ａ）に示す様に、前記セラミックスにより中空円筒状のローラ１２０を形成し、該ローラの外周部１２１にワイヤー溝１０を形成する。このローラ１２０は前記第１実施例と異なり中空部１２３内に補強部材がないので、強度を維持するため、その肉厚Ｒｔは、第１実施例のそれより厚く、例えば、２倍の厚さに形成される。

【００６２】（２）図１３（Ｂ）に示す様に、前記セラミックスにより中空円筒状のローラ１３０を形成し、該ローラ１３０の外周部１３１にワイヤー溝１０を形成する。このローラ１３０の一端にはベアリング軸部１３５が設けられ、他端には円錐台状の軸受部１３６が設けられている。なお、ベアリング軸部１３５はベアリングとのなじみを良くするために、金属１３８で覆われている。

【００６３】

【発明の効果】この発明は次の様な顕著な効果を奏する。

（１）セラミックス製ローラが、アルミナ９０％以上のセラミックスで形成されているので、ワイヤ溝間山の山頂幅を狭くしても、チッピングが発生しない。そのため、従来例に比べワイヤ溝の溝ピッチを大幅に小さくすることができる。

【００６４】（２）セラミックス製ローラが、曲げ強度３５００ｋｇ／ｃｍ^{2}以上のセラミックスで形成されているので、ワイヤ溝間山の山頂幅を狭くしても、チッピングが発生しない。そのため、従来例に比べワイヤ溝の溝ピッチを大幅に小さくすることができる。

【００６５】（３）該ワイヤ溝の深さが、５０～５００μｍであり、該ローラの中心軸に対するワイヤ溝のラジアル方向の振れが２０μｍ以下であり、該ローラの中心軸に対するワイヤ溝のアキシャル方向の振れが２０μｍ以下であるので、従来例に比べワイヤ溝の深さが浅くなり、又、浅くしても脱線や断線が発生しない。そのため、ワイヤ溝の加工時間および費用が従来例に比べ著しく減少する。

【図面の簡単な説明】

【図１】本発明の第１実施例を示す縦断面図で、図４のＩ－Ｉ線断面図である。

【図２】図１のＩＩ－ＩＩ線断面図である。

【図３】図１の拡大図の一部を示す図である。

【図４】使用状態を示す図である。

【図５】図４のＶ－Ｖ線断面図である。

【図６】脱線計算図を示す概念図である。

【図７】第２実施例を示す縦断面図である。

【図８】第３施例を示す断面図の要部を示す図である。

【図９】アルミナ純度とチッピング発生山頂幅と関係を示す図である。

【図１０】チッピング発生時の山頂幅を曲げ強度との関係を示す図である。

【図１１】本発明の第６実施例を示す図である。

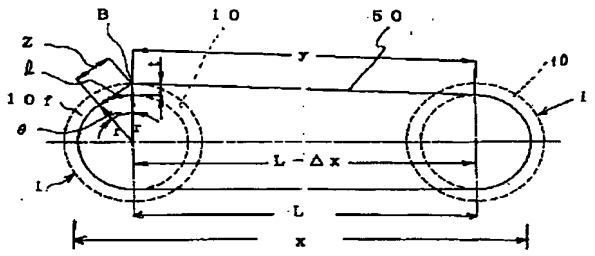
【図１２】本発明の第７実施例を示す図である。

【図１３】本発明の第８実施例を示す図である。

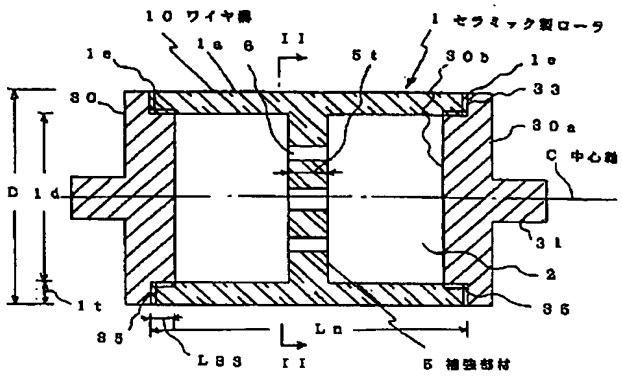
【符号の説明】

１	セラミックス製多溝ローラ
２	中空部
５	補強部材
１０	ワイヤー溝
３０	金属製支持部材
５０	ワイヤー
ＡＸ	多溝ローラのワイヤ溝のアキシャル方向
ＡＲ	多溝ローラのワイヤ溝のラジアル方向

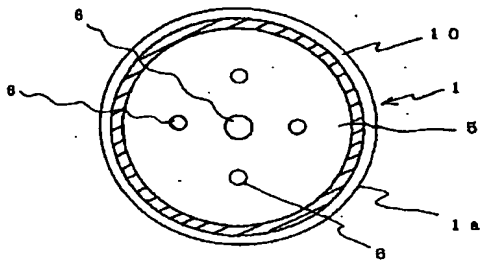
【図６】



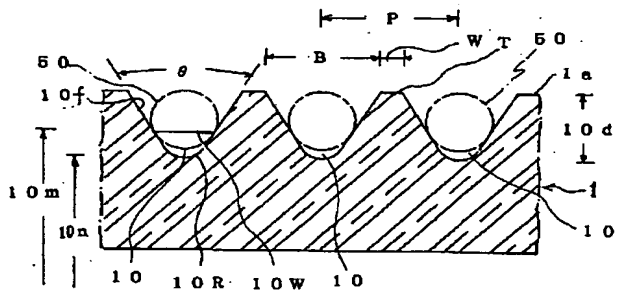
【図１】



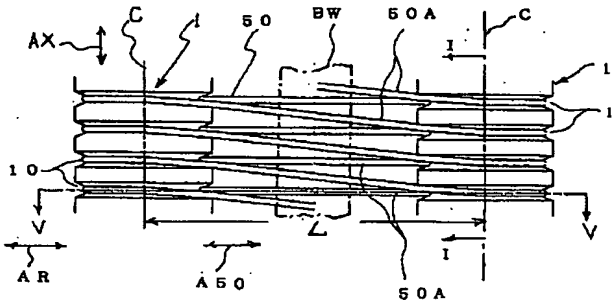
【図２】



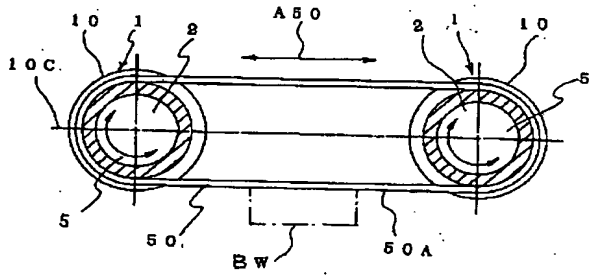
【図３】



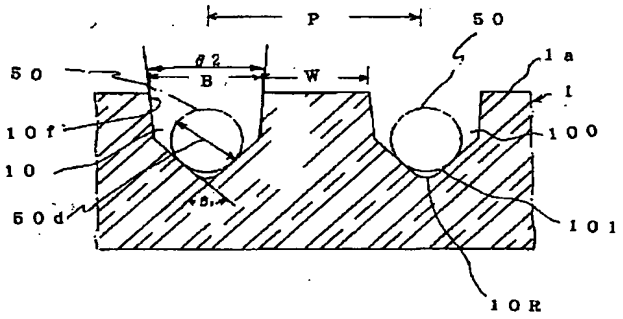
【図４】



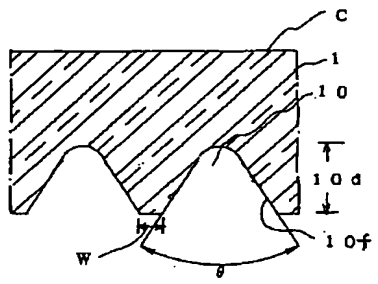
【図５】



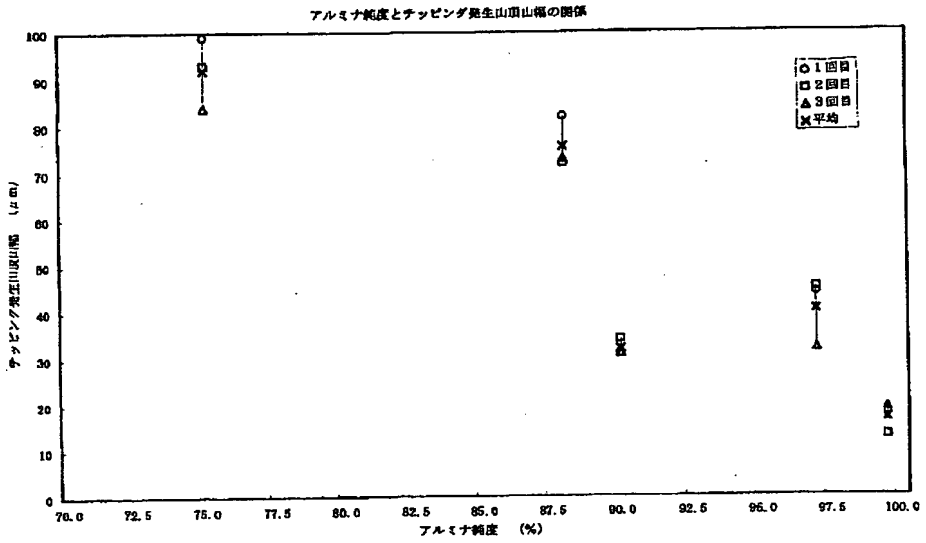
【図７】



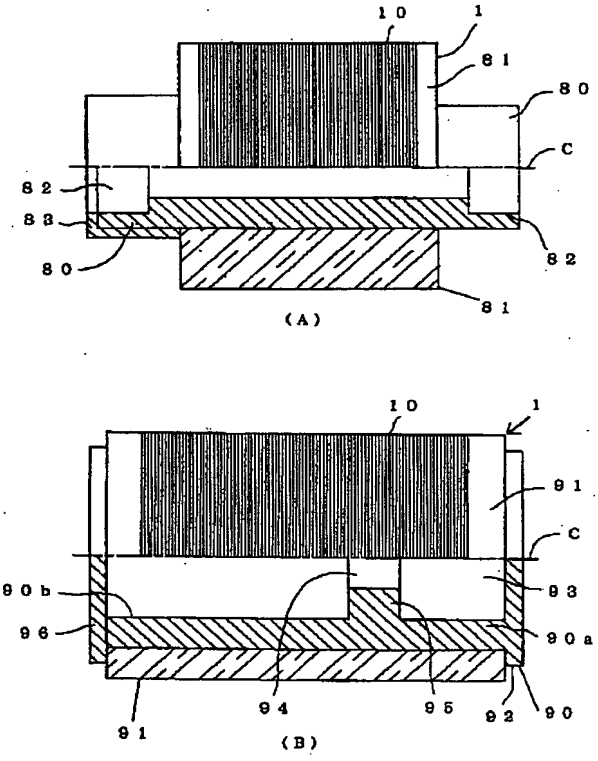
【図８】



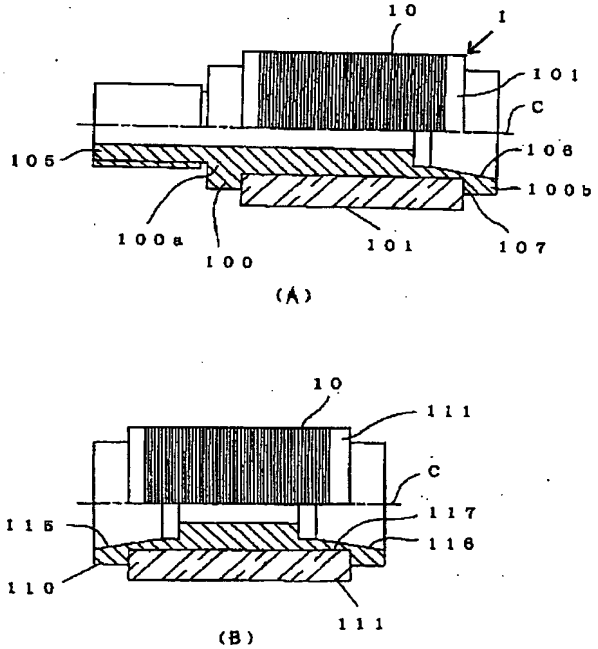
【図９】


アルミナ純度とチッピング発生山頂山幅の関係
チッピング発生山頂山幅 (μm)
アルミナ純度 (%)
1回目
2回目
3回目
平均
0
10
20
30
40
50
60
70
80
90
100
70.0
72.5
75.0
77.5
80.0
82.5
85.0
87.5
90.0
92.5
95.0
97.5
100.0

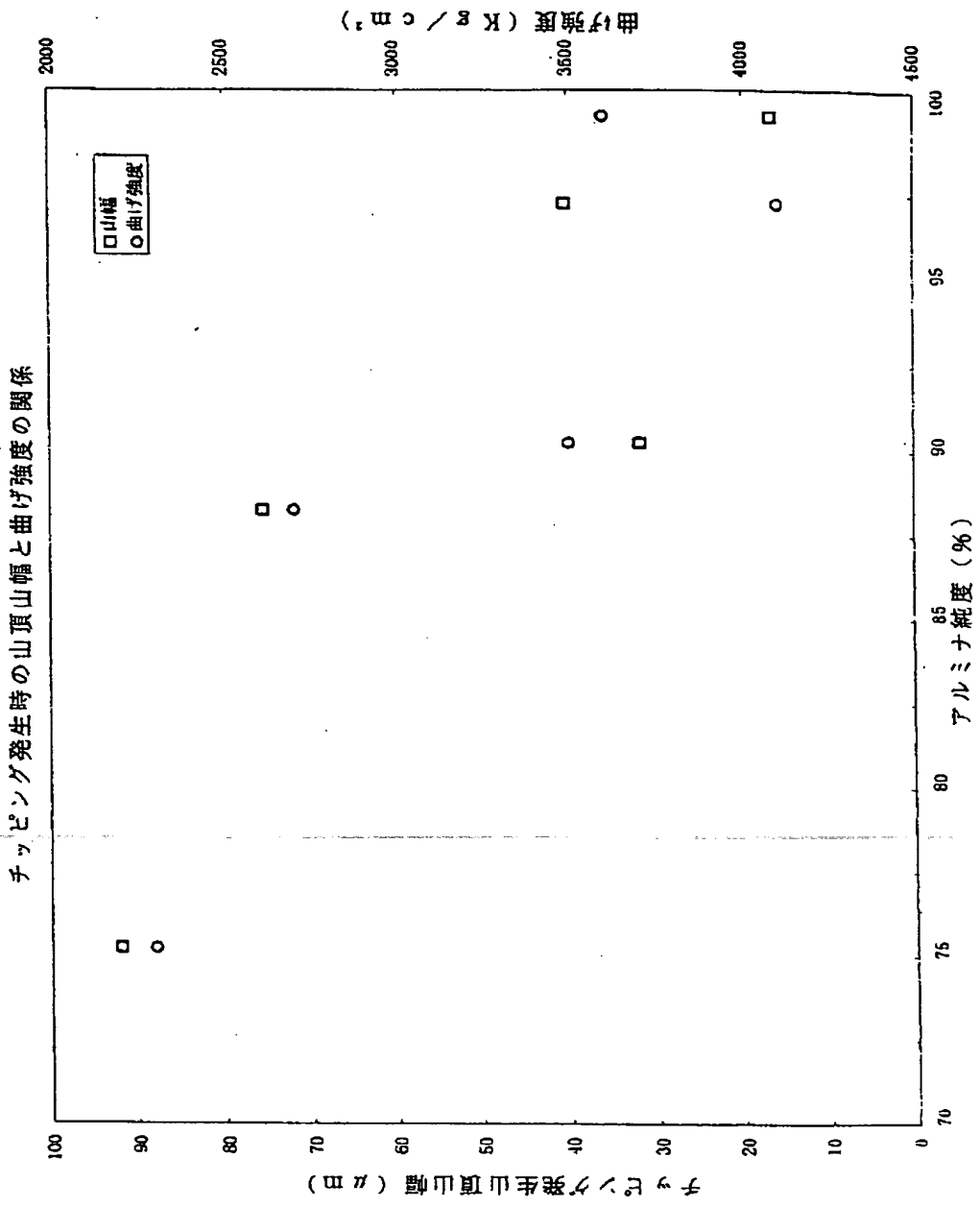
【図１１】


10
1
81
80
C
82
83
80
82
81
(A)
10
1
91
C
90b
93
96
90a
91
94
95
92
90
(B)

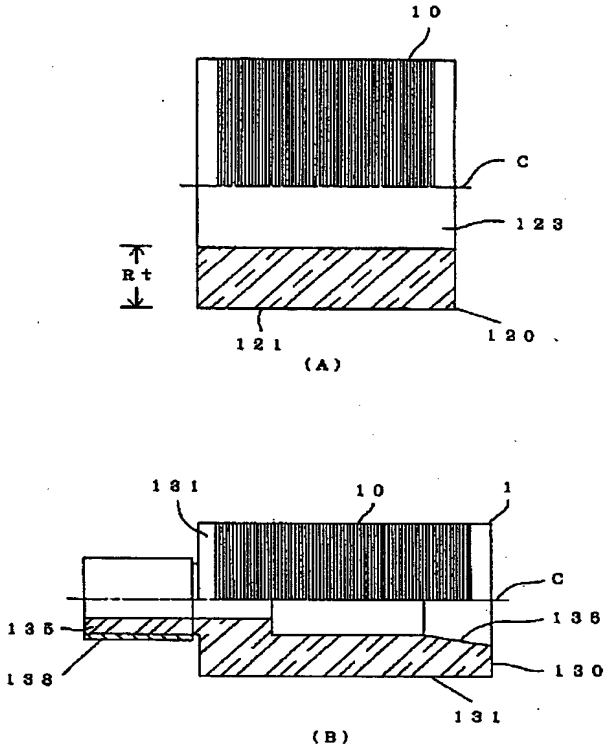
【図１２】


10
1
101
C
105
108
100b
100a
100
101
107
(A)
10
111
C
117
115
116
110
111
(B)

【図１０】


チッピング発生時の山頂山幅と曲げ強度の関係
チッピング発生山頂山幅（μm）
曲げ強度（Kg／cm²）
アルミナ純度（%）
□山幅
○曲げ強度
0
10
20
30
40
50
60
70
80
90
100
2000
2500
3000
3500
4000
4500
70
75
80
85
90
95
100

【図１３】



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3.In the drawings, any words are not translated.

CLAIMS

[Claim(s)]
[Claim 1] The multi-slot roller made from the ceramics of the wire saw characterized by forming the alumina content for the slot formation part of; this multi-slot roller made from the ceramics with 90% or more of ceramics in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama on a front face.
[Claim 2] The multi-slot roller made from the ceramics of the wire saw characterized by forming the slot formation part of; this multi-slot roller made from the ceramics in a front face with the ceramics with a flexural strength of 3500kg/cm2 or more in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama.
[Claim 3] Two or more multi-slot rollers which have two or more wire slots on a front face, and are arranged in it in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of rollers made from the ceramics the wire depth of flute of; this multi-slot roller made from the ceramics It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, The multi-slot roller made from the ceramics of the wire saw by which it is characterized.
[Claim 4] Two or more multi-slot rollers which have two or more wire slots on a front face, and are arranged in it in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of rollers made from the ceramics; this multi-slot roller made

from the ceramics The con[redacted]t of an alumina is formed with[redacted]% or more of ceramics. The wire depth of flute of this multi-slot roller It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller slot is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, The multi-slot roller made from the ceramics of the wire saw by which it is characterized.

[Claim 5] Two or more multi-slot rollers which have two or more wire slots on a front face, and are arranged in it in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of rollers made from the ceramics; this multi-slot roller made from the ceramics It is formed with the ceramics with a flexural strength of 3500kg/cm2 or more. The wire depth of flute of this multi-slot roller It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, The multi-slot roller made from the ceramics of the wire saw by which it is characterized.

[Claim 6] Claims 1, 2, 3, and 4 to which dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics is characterized by being 30 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 7] Claims 1, 2, 3, and 4 to which accumulation of the error of the slot pitch of the one multi-slot roller made from the ceramics is characterized by being 30 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 8] Claims 1, 2, 3, and 4 characterized by for dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics being 30 micrometers or less, and accumulation of the error of the pitch of this wire slot being 30 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 9] Claims 3 and 4 characterized by the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece being 60 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 10] Claims 3 and 4 characterized by the mutual cumulative error of the slot pitch of the wire slot which faces of the two multi-slot roller made from the ceramics which counters a workpiece being 60 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Claim 11] Claims 3 and 4 characterized by for the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece being 60 micrometers or less, and the mutual

cumulative error of the slo[redacted]tch of this wire slot that faces [redacted]ng 60 micrometers or less, or the multi-slot roller made from the ceramics of a wire saw given in five.

[Translation done.]

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3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention] When this invention is further described about the wire saw which cuts silicon, the magnetic substance, Xtal, etc., it relates to the multi-slot roller made from the ceramics of a wire saw.
[0002]
[Description of the Prior Art] The wire saw is equipped with two or more multi-slot rollers which stretched the wire, and cuts workpieces (work piece), such as silicon, the magnetic substance, Xtal, and ceramics, by rotating this multi-slot roller and carrying out rectilinear motion of this wire.
[0003] The conventional multi-slot roller is formed with resin, for example, nylon, and two or more wire slots are established in the front face. Although usually formed in 0.5-1mm, since that quality of the material is flexible and workability is also good, while processing of a wire slot is easy for this wire depth of flute, since it tends to wear it out, it has a problem in endurance. Then, in order to solve said problem in recent years, the roller made from the ceramics is used (refer to JP,63-237863,A).
[0004]
[Problem(s) to be Solved by the Invention] The degree of hardness of the ceramics is remarkably high compared with nylon, for example, although the Rockwell hardness of 66 nylon is R112, since the degree of hardness of the ceramics whose content of an alumina is 97% is too high, the measurement with Rockwell hardness is impossible. Then, it was Hv1400 when the Vickers hardness of this ceramics was measured. This Hv1400 is too high and the comparison with Rockwell hardness cannot do it.
[0005] Deformation or a wire expanded and contracted, and when the wire slot of a multi-slot roller was formed from nylon, the wire slot was compensating the precision error of a wire slot. However, since a wire slot does not deform when this wire slot is

formed with the ceramics, [illegible]y when a wire expands and co[illegible]acts all the precision errors of a wire slot, it must compensate. Many [therefore, / when a wire slot is formed with the ceramics / farther than the case where the stress concerning a wire has a wire slot formed from nylon]

[0006] The multi-slot roller made from the ceramics of a wire saw must form a wire slot from the above-mentioned situation in a precision far higher than the multi-slot roller made of nylon.

[0007] The multi-slot roller made of nylon had processed the wire slot by cutting by the cutting tool using NC engine lathe. However, when processing the wire slot of the roller made from the ceramics, since a degree of hardness is very high, the ceramics becomes a grinding process by the diamond wheel using NC cylindrical grinder as mentioned above. Therefore, while the time amount which processing takes compared with the conventional example becomes remarkably long, processing costs also come to increase.

[0008] Moreover, grinding stones may have to be exchanged, as wear at the tip of a grinding stone is intense and is recessing of the one multi-slot roller made from the ceramics. However, if this grinding stone is exchanged, it will be difficult to double with the condition in front of exchange of the physical relationship of a wire slot and this grinding stone precisely, and it will become the error factor of the slot pitch of a result wire slot. Therefore, a wire slot cannot be precisely formed as a design, but it may become the cause of derailment and an open circuit.

[0009] Then, it is possible by making the wire depth of flute shallower than the conventional multi-slot roller made of nylon to solve said problem. However, if a wire slot is made shallow, it will become easy to generate derailment of a wire, and if a wire derails, the workpiece under cutting (work piece) will be spoiled.

[0010] Moreover, since the multi-slot roller made from the ceramics does not almost have deformation as mentioned above, high tension is used for a wire from the multi-slot roller made of nylon in many cases for the improvement in process tolerance, and the improvement in working speed, hanging on it. Furthermore, in order that this multi-slot roller may reduce the amount of shaving of a workpiece (work piece), and in order to cut much quantity at once, the wire of a thin path, for example, piano wire with a diameter of 0.1mm, is used. Therefore, if many loads are applied to a wire even when it is smaller than a design value on a wire, it will disconnect.

[0011] Furthermore, in recent years, diversification of a workpiece (work piece) progresses and the slot pitch of the wire slot demanded in connection with it is also crossed to a variety. When processing a workpiece into ultrathin especially, less than [slot pitch 0.2mm] is required, but if this slot pitch becomes small, naturally in proportion to it, slot Mayama's summit-of-the-mountain flight width will also become small. However, since the multi-slot roller made from the ceramics is a hard and brittle

nature ingredient, if a summit-of-the-mountain flight width is made small, a chipping will generate it in slot Mayama at the time of wire recessing. Therefore, it becomes difficult to form slot Mayama as a design. When slot Mayama cannot form as a design, derailment of a wire and an open circuit occur or it has a bad influence also on the process tolerance of a workpiece (work piece).

[0012] This invention is making it a chipping not occur in view of the above-mentioned situation at the time of recessing. Other purposes aim at making it derailment and an open circuit not arise while they make the wire depth of flute shallower than that of the conventional example.

[0013]

[Means for Solving the Problem] the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the content of an alumina for the slot formation part of; this multi-slot roller made from the ceramics with 90% or more of ceramics in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama on the front face -- it comes out. the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the slot formation part of; this multi-slot roller made from the ceramics in a front face with the ceramics with a flexural strength of 3500kg/cm2 or more in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama -- it is.

[0014] Two or more multi-slot rollers which this invention has two or more wire slots on a front face, and are arranged in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of multi-slot rollers made from the ceramics the wire depth of flute of; this multi-slot roller made from the ceramics It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, the multi-slot roller made from the ceramics of the wire saw by which it is characterized -- it comes out. In this invention dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics So that it may be 30 micrometers or less and accumulation of the error of the pitch of this wire slot may be 30 micrometers or less form or Moreover, you may form so that the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece may be 60 micrometers or less and the mutual cumulative error of the slot pitch which this wire slot faces may be 60 micrometers or less.

[0015]
[Embodiment of the Invention] When this invention person was narrow, for example, slot Mayama's summit-of-the-mountain flight width was set to 40 micrometers or less, he experimented in whether a chipping occurs or not, having thought that that a chipping occurs would not have a problem in the quality of the material, and changing the content of an alumina component. Consequently, when the content of an alumina became 90% or more and flexural strength became 3500kg/cm2 or more, it turned out that a chipping does not occur, for example even if set to 40 micrometers even if slot Mayama's summit-of-the-mountain flight width becomes narrow. Then, we decided that the content of an alumina adopts 90% or more of ceramics, or the ceramics with a flexural strength of 3500kg/cm2 or more as the quality of the material of the multi-slot roller made from the ceramics.
[0016] what a wire tends to derail or disconnect this invention person to in the case of the multi-slot roller made from the ceramics -- a wire slot -- the multi-slot roller made of nylon -- comparing -- deformation -- **** -- I thought that it was because it is few. That is, although the wire slot is compensating precision, such as a deflection of the wire slot of a multi-slot roller, with the multi-slot roller made of nylon when deformation or a wire develops, most adjustments by deformation of a wire slot cannot be found, and are compensating all precision with the multi-slot roller made from the ceramics only with the wire.
[0017] Although what is necessary is just to form a wire slot precisely so that it may be without error to a design value in order to prevent derailment of a wire, and an open circuit, it is very difficult to form such. Then, when this invention person pursued the cause of derailment and an open circuit, it turned out that the main cause is in the deflection (henceforth the deflection of the axial direction) of the axial direction of the wire slot to the green sand core shaft of a multi-slot roller, and the deflection (henceforth the deflection of a radial direction) of the radial direction of the wire slot to the green sand core shaft of a multi-slot roller.
[0018] Then, even if these deflections arose, when it asked for the range which is not derailed and disconnected, i.e., the tolerance of a deflection, 20 micrometers or less of deflections of 20 micrometers or less and a radial direction came out [the wire depth of flute / the deflection of the axial direction] in the wire slot of the 50-500-micrometer multi-slot roller made from the ceramics, and a certain thing was understood.
[0019] Furthermore, when the following conditions were fulfilled, it turned out that it is more desirable.
(1) The path of the bay which connects the point that the path and wire of the path of the wire slot of an one multi-slot roller, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and ********** should be 30 micrometers or less.

(2) The path of the bay wh[redacted] connects the point that the pat[redacted]nd wire of the diameter of the wire slot of each of this **** roller of the two multi-slot roller made from the ceramics which counters a workpiece, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and the sum total of ********** should be 60 micrometers or less.

[0020] (3) The slot pitch cumulative error of the wire slot of an one multi-slot roller should be 30 micrometers or less.

(4) The cumulative error of the slot pitch of the wire slot where the two multi-slot roller made from the ceramics which counters a workpiece faces should be 60 micrometers or less. Then, it decided to adopt the wire slot in the above tolerance as processing conditions.

[0021] In addition, although the wire slot of the multi-slot roller made from the ceramics must be formed so that a wire can be attached, **** selection of the configuration, magnitude, the number, etc. is made if needed. For example, it is made a configuration to which a wire contacts the groove bottom of a wire slot, and is formed in a configuration to which a wire contacts the both-sides wall of a wire slot.

[0022] Moreover, 90% or more of purity, i.e., the content of an alumina, is used for 90% or more of ceramics, a zirconia, silicon carbide, silicon nitride, etc. as ceramics which forms a multi-slot roller.

[0023]

[Example 1] Drawing 1 - drawing 6 explain the first example of this invention. the multi-slot roller 1 made from the ceramics of a wire saw is formed in the bell shape with the ceramics, the outer diameter D comes out 40mm, and the bore of 1d comes out out of 20mm and die length Ln 100mm. As this ceramics, the ceramics whose content of an alumina is 90 97%% or more, for example, purity, is used.

[0024] The reinforcement member 5 is formed in the centrum 2 of this multi-slot roller 1. This reinforcement member 5 is the disk configuration of the shape of the said heart formed in this multi-slot roller 1 and one. 5t in thickness of the reinforcement member 5 of this disk configuration -- the same thickness as thickness 1t=10mm of the multi-slot roller 1 -- it comes out, it is, and although both ratio of wall thickness to outside diameter 1t/5t is 1, this ratio of wall thickness to outside diameter 1t/5t is chosen in consideration of the rigidity of a multi-slot roller etc.

[0025] Although one reinforcement member 5 of a disk configuration is formed, when **** selection also of this arrangement number is made in consideration of the die length Ln of this multi-slot roller 1 etc., for example, the reinforcement member 5 of three disk configurations is arranged in the direction of green sand core shaft C at equal intervals, the reinforcement member 5 may be omitted conversely.

[0026] In the reinforcement member 5 of a disk configuration, five holes 6 for

lightweight-izing are established, and lightweight-ization of the reinforcement member 5 is attained by this hole 6 for lightweight-izing to it. In consideration of the rigidity of the multi-slot roller 1 demanded, **** selection of the location of this hole 6 for lightweight-izing, the number, the configuration, etc. is made, for example, the hole 6 for lightweight-izing has not penetrated, or the eight polygon-like holes 6 for lightweight-izing are adopted.

[0027] Spacing is set in surface 1a of this multi-slot roller, and two or more wire slots 10 are formed in the direction of green sand core shaft C at it. This wire slot 10 is precisely processed based on engineering drawing with NC cylindrical grinder which is not illustrated. For example, the wire channel depth 10d=0.12mm, the slot include angle of theta= 60 degrees, the slot pitch of P= 0.24mm, a flute width = it is formed in 0.2mm, slot Mayama's summit-of-the-mountain flight width of W= 0.04mm, and 296 slots.

[0028] The metal supporter material 30 formed disc-like is formed in both-ends 1e of this multi-slot roller 1. A shank 31 is arranged in the center section of outside 30a of this metal supporter material 30, and the fitting section 33 is formed in the periphery section of the inside 30b. Although fitting of this fitting section 33 is carried out to edge 1e of the multi-slot roller 1, these both sections 33 and 1e are pasted up with the adhesives 35, such as an epoxy resin.

[0029] Since these Ryobe's 33 and 1e junction die length L33 is very shorter than the die length Ln of the multi-slot roller 1, a temperature change arises by operating the equipment of a wire saw, and even if both expand, contract and displace, Ryobe's junction condition is maintained. In addition, as for this metal supporter material 30, it is desirable to be formed in a disk configuration with the ingredient of coefficient of thermal expansion [**** / the same as that of the coefficient of thermal expansion of the ceramics or], although iron, steel, etc. are generally used, for example, titanium, a titanium alloy, etc. are used as this ingredient.

[0030] Next, actuation of a wire saw is explained. The multi-slot roller attachment part of the wire saw which is not illustrated is equipped with the shank 31 of the multi-slot roller 1. The wire 50 of one 0.12mm diameter is twisted around the wire slot 10 which faces, surrounding two or more of these multi-slot rollers 1 with which it was equipped, and much wire train 50A is formed. at this time, dispersion with a diameter [the diameter of 10n of the wire slot of an one multi-slot roller], i.e., the diameter of wire groove bottom 10R, and a diameter [of bay 10W which connect the contacting point that 10f of side attachment walls and the wire of both sides of a wire slot contact] of 10m is 30 micrometers or less, and 30 micrometers or less of cumulative errors of the slot pitch P of this wire slot come out.

[0031] Moreover, the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters the

workpiece currently used within 1 equipment, Namely, the diameter of 10n of wire groove bottom 10R of each multi-slot roller made from the ceramics, The sum total of dispersion with a diameter [of bay 10W which connect the contacting point that 10f of side attachment walls and the wire of both sides of a wire slot contact] of 10m is 60 micrometers or less, and the accumulation of the mutual error of the slot pitch P which the multi-slot roller made from the ceramics which faces faces is 60 micrometers or less.
[0032] Round trip or one direction rectilinear motion of the wire train 50A is carried out like an arrow head A50 by reversal-going or one direction rotating a multi-slot roller. the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of the multi-slot roller 1 made from the ceramics at this time is 20 micrometers or less, and 20 micrometers or less of deflections of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 made from the ceramics come out of it.
[0033] While pressing Workpiece (work piece) BW against this wire 50, abrasives are cut from the regurgitation nozzle which is not illustrated, making an abrasive material intervene between discharge and both.
[0034] Although inertial force occurs with rotation of this multi-slot roller 1 made from the ceramics, since this multi-slot roller 1 is very lightweight compared with the conventional example, it will become very small [that inertial force].
[0035] Moreover, although a temperature change may arise at the time of operation of a wire saw and both this multi-slot roller 1 made from the ceramics and the metal supporter material 30 may expand and contract, if both 1 and 30 are in abbreviation etc. by carrying out and coefficient of thermal expansion is made from them, since it expands and contracts in coincidence at an abbreviation same rate and the exfoliation like jointing etc. will not occur, it is desirable.
[0036] Although the deflection of a wire slot occurs at the time of operation of the above-mentioned wire saw, the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less, and the deflection of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less.
[0037] As a result of performing cutting processing of the silicon whose diameter is 8 inches in the wire saw which used the above-mentioned multi-slot roller made from the ceramics, derailment of a wire, an open circuit, etc. did not occur, and exfoliation of the ceramic section and metal supporter material etc. was not seen, but the dimensional accuracy of the wafer which is a workpiece was able to maintain 5 micrometers or more, and was able to be processed.
[0038] The tolerance of the deflection of the wire slot of radial direction AR to the green sand core shaft C of the multi-slot roller 1 made from the ceramics in this example is called for also by count. The tolerance of this deflection shows the limitation of the

deflection which derailment generates.
[0039] Next, said tolerance is calculated by drawing 6 which is the derailment nomogram of this example. Although various causes are put together and derailment of the wire of a wire saw is generated, the progress of the derailment is as follows.
(1) In order that the wire which has run from the next wire slot may enter aslant to a wire slot, a wire 50 contacts 10f of side attachment walls of this wire slot like [near B of drawing 6].
[0040] (2) This wire receives rotation of the multi-slot roller 1 made from the ceramics, and the force to the direction of a periphery of 10f of side attachment walls.
(3) The green sand core shaft C spacing L between the two multi-slot rollers which counters becomes short by the deflection of radial direction AR of the wire slot of the multi-slot roller made from the ceramics, and a wire 50 loosens and derails.
[0041] The following relational expression is called for from drawing 6 which shows the time of this derailment.
Y+z=L+l+delta x (1)
costheta=r/(r+t) (2)
l=2pi rxtheta / 360 (3)
r2+z2=(r+t)2 (4)
(L-delta x) 2+t2=y2 (5)
[0042] In the above-mentioned formula, the amount of deflections of the wire slot of a precise distance, the die length of l:rádii, an r:multi-slot roller, and the radius of the contact part of a wire, the wire migration length at the time of t:derailment initiation and a deltax:multi-slot roller is shown theoretically between L:multi-slot rollers, respectively.
[0043] The above-mentioned formula (1) From - (5), the deflection of the wire slot of the multi-slot roller which derailment generates is searched for. Next, the example of count is shown.
The example 1 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment generates.
L= 100 Unit [mm]
r= 20t=0.4[0044]
(2) Formula COStheta=20/(20+0.4) =0.98039 Theta=COS - 10.98039= 11.365 degrees
(3) types l=2pix20x11.365 / 360= 3.9671 (4) types Z=root (r+t) (2-r2)
= root (20+0.4) (2-202)
= 4.0200 [0045] From (1) and (5) types (L-delta x) 2+t2=(L+l+delta x-z) 2 therefore (100-deltax) 2+0.42 = (100+3.967-4.0200+deltax) [2] 10000-200delta x+delta x2 +0.16 =9989.4028+199.894deltax+2deltax2 therefore deltax2+399.894deltax-10.757=0 deltax=26.9[mum] [0046] The example 2 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment

generates.
L= 100 Unit [mm]
r= It calculates like the example 1 of 30t=0.4 count, and is deltax=21.7[mum].
[0047] Although the amount delta x of deflections of the wire slot of the multi-slot roller made from the ceramics was calculated by the above-mentioned example of count, as for the deflection of radial direction AR of a wire slot to the green sand core shaft C of the multi-slot roller made from the ceramics, it is desirable to manufacture so that it may be set to 20 micrometers or less from said examples 1 and 2 of count.
[0048]
[Example 2] Drawing 7 explains the 2nd example of this invention. The difference of this example and 1st example is as follows. the cross-section configuration of the wire slot 10 -- setting -- slot include-angle theta1=90 degree of a base, and the slot include angle theta of a side attachment wall -- they are 2= 10 degrees, the flute width of B= 0.3mm, slot Mayama's summit-of-the-mountain flight width of W= 0.1mm, channel depth 10d=0.3mm, and slot pitch =0.4mm.
[0049]
[Example 3] Drawing 8 explains the 3rd example of this invention. The next experiment was conducted in order to know the relation between the alumina content (purity %) of the multi-slot roller made from the ceramics or flexural strength, and the summit-of-the-mountain flight width of slot Mayama whom a chipping does not generate at the time of processing. As shown in drawing 8 , the maximum summit-of-the-mountain flight width W as which 1 micrometer of wire slots 10 of the same configuration is narrowed from each pitch 0.4mm on the multi-slot roller 1 made from the ceramics with which alumina contents differ, and generating of a chipping is regarded in this each **** roller was investigated. In addition, the processing conditions are as follows.
[0050] processing machine: -- NC cylindrical-grinder grinding stone: -- the result of a diamond wheel, the grain-size #400 processing work-piece (alumina material):diameter of 65mm, the die-length rotational frequency [of 100mm] 200rpm processing quirk-like:slot include angle of theta= 60 degrees, and a channel depth 10d= 0.15mm experiment is shown in Table 1 and drawing 9 , and drawing 10 .
[0051]
[Table 1]

アルミナ純度（%）	チッピング発生最大山幅（μm）				曲げ強度（kg／cm²）
	実験1	実験2	実験3	平均	
75	99	93	84	92.0	2300
88	82	72	73	75.6	2700
90	31	34	31	32.0	3500
97	44	45	32	40.3	4100
99.5	18	13	19	16.7	3600

[0052] Drawing 9 is drawing showing the relation between an alumina content (axis-of-abscissa %), i.e., alumina purity, and a chipping generating summit-of-the-mountain flight width (axis-of-ordinate mum). In this drawing, as for the 2nd experimental result and the trigonum mark, the 1st experimental result and the square mark show an average for a round mark, as for the 3rd experimental result and x mark.
[0053] Drawing 10 is drawing showing the relation between alumina purity (axis-of-abscissa %), a chipping generating summit-of-the-mountain flight width (left axis-of-ordinate mum), and flexural strength (right axis-of-ordinate kg/cm2). In this drawing, the square mark shows a summit-of-the-mountain flight width, and a round mark shows flexural strength.
[0054] Table 1 and drawing 9 , and drawing 10 showed that 75% of alumina contents, 88% of thing or the flexural strength of 2300kg/cm2, and the summit-of-the-mountain flight width of a 2700kg/cm2 thing had the large quality of the material 2 or 3 or more times compared with the summit-of-the-mountain flight width of a thing (90% of alumina purity, 92%, 97%, and 99.5% of thing or the flexural strength of 3500kg/cm2, 4100kg/cm2, and 3600kg/cm2). That is, it turned out that a chipping does not occur even if it will make extremely narrow the summit-of-the-mountain flight width W, if the content of an alumina becomes 90% or more or the flexural strength of 3500kg/cm2 or more.
[0055]
[Example 4] The 4th example of this invention is explained. The chipping was not generated, although the diamond wheel was used for the multi-slot roller with a diameter of 60mm which consists of an alumina of 97% of purity made from the ceramics and the wire slot with a slot pitch [of P= 0.3mm] and a summit-of-the-mountain flight width [of

slot Mayama] of W= 50 micrometers was processed into it. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of Xtal was performed, cutting with a as precise thickness precision as 5 micrometers or more was performed. Although the wire slot was ground faint [every] with the abrasive grain adhering to a wire and was worn out, it was able to maintain the above-mentioned precision over the long time of 300 hours, and was able to perform cutting processing.
[0056]
[Example 5] The 5th example of this invention is explained. Although the diamond wheel was used for the multi-slot roller made from the ceramics of the same specification as the above which consists of an alumina of 97% of purity and the wire slot with a wire slot pitch [of P= 0.25mm] and a summit-of-the-mountain flight width [of slot Mayama] of W= 40 micrometers was processed into it, the chipping was not generated like the example 4. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of the magnetic substance was performed, it came out to maintain 5 micrometers or more like the above, and the thickness precision of a work piece came.
[0057]
[Example 6] Drawing 11 explains the 6th example of this invention. A roller does not necessarily need to form all with said ceramics, and if the slot formation part is formed with said ceramics, it is sufficient for it. The example is as follows.
(1) As shown in drawing 11 (A), form the cylindrical periphery section 81 made from said ceramics with which the wire slot 10 stuck to the metal pipe 80. The stop member 83 for an applied part 82 being formed in the both ends of this metallic pipe 80, and fixing the periphery section 81 to an end is formed.
[0058] (2) As shown in drawing 11 (B), form the cylindrical periphery section 91 made from said ceramics with which the wire slot 10 stuck to the metal pipe 90. The **-like ring part 92 is formed, the reinforcement disk 95 with which the hole 94 opened is formed in a centrum 93, and the lid 96 which fixes this periphery section 91 is fixed to other end 90b by end 90a.
[0059]
[Example 7] Drawing 12 explains the 7th example of this invention. A slot formation part is formed with said ceramics, and this example as well as said 6th example is a case.
(3) As shown in drawing 12 (A), form the cylindrical periphery section 101 made from said ceramics with which the wire slot 10 stuck to the metal pipe 100. The bearing shank 105 is formed in end 2100a of this metal pipe 100, and the truncated-cone-like bearing 106 is formed in other end 100b. The cylindrical crevice 107 is formed in the periphery of this pipe 100, and said cylindrical periphery section 101 is being attached and fixed to this crevice 107.
[0060] (4) As shown in drawing 12 (B), form the cylindrical periphery section 111 made

from said ceramics with w[redacted]h the wire slot 10 stuck to the m[redacted]tal pipe 110. The truncated-cone-like bearings 115 and 116 are formed in the both ends of this metal pipe 110. The cylindrical crevice 117 is formed in the periphery of this pipe 110, and said cylindrical periphery section 111 is attached and fixed to it by this crevice 117.
[0061]
[Example 8] Drawing 13 explains the 7th example of this invention. In said example, although the slot formation part was formed with said ceramics, this whole multi-slot roller made from the ceramics can also be formed with said ceramics. The example is as follows.
(1) As shown in drawing 13 (A), form the bell shape roller 120 with said ceramics, and form the wire slot 10 in the periphery section 121 of this roller. Since this roller 120 does not have a reinforcement member into a centrum 123 unlike said 1st example, in order to maintain reinforcement, that thickness Rt is thicker than that of the 1st example, for example, is formed in twice as many thickness as this.
[0062] (2) As shown in drawing 13 (B), form the bell shape roller 130 with said ceramics, and form the wire slot 10 in the periphery section 131 of this roller 130. The bearing shank 135 is formed in the end of this roller 130, and the truncated-cone-like bearing 136 is formed in the other end. In addition, the bearing shank 135 is covered with the metal 138, in order to improve concordance with bearing.
[0063]
[Effect of the Invention] This invention does the following remarkable effectiveness so.
(1) Since the roller made from the ceramics is formed with the ceramics beyond alumina 90%, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.
[0064] (2) Since the roller made from the ceramics is formed with the ceramics with a flexural strength of 3500kg/cm2 or more, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.
[0065] (3) Since this wire depth of flute is 50-500 micrometers, the deflection of the radial direction of the wire slot to the medial axis of this roller is 20 micrometers or less and the deflection of the axial direction of the wire slot to the medial axis of this roller is 20 micrometers or less, compared with the conventional example, the wire depth of flute becomes shallow, and even if it makes it shallow, neither derailment nor an open circuit occurs. Therefore, the floor to floor time and costs of a wire slot decrease remarkably compared with the conventional example.

[Translation done.]

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TECHNICAL FIELD

[Field of the Invention] When this invention is further described about the wire saw which cuts silicon, the magnetic substance, Xtal, etc., it relates to the multi-slot roller made from the ceramics of a wire saw.

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PRIOR ART

[Description of the Prior Art] The wire saw is equipped with two or more multi-slot rollers which stretched the wire, and cuts workpieces (work piece), such as silicon, the magnetic substance, Xtal, and ceramics, by rotating this multi-slot roller and carrying out rectilinear motion of this wire.
[0003] The conventional multi-slot roller is formed with resin, for example, nylon, and two or more wire slots are established in the front face. Although usually formed in 0.5-1mm, since that quality of the material is flexible and workability is also good, while processing of a wire slot is easy for this wire depth of flute, since it tends to wear it out, it has a problem in endurance. Then, in order to solve said problem in recent years, the roller made from the ceramics is used (refer to JP,63-237863,A).

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EFFECT OF THE INVENTION

[Effect of the Invention] This invention does the following remarkable effectiveness so.
(1) Since the roller made from the ceramics is formed with the ceramics beyond alumina 90%, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.
[0064] (2) Since the roller made from the ceramics is formed with the ceramics with a flexural strength of 3500kg/cm2 or more, even if it narrows wire slot Mayama's summit-of-the-mountain width of face, a chipping does not occur. Therefore, compared with the conventional example, the slot pitch of a wire slot can be sharply made small.
[0065] (3) Since this wire depth of flute is 50-500 micrometers, the deflection of the radial direction of the wire slot to the medial axis of this roller is 20 micrometers or less and the deflection of the axial direction of the wire slot to the medial axis of this roller is 20 micrometers or less, compared with the conventional example, the wire depth of flute becomes shallow, and even if it makes it shallow, neither derailment nor an open circuit occurs. Therefore, the floor to floor time and costs of a wire slot decrease remarkably compared with the conventional example.

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] The degree of hardness of the ceramics is remarkably high compared with nylon, for example, although the Rockwell hardness of 66 nylon is R112, since the degree of hardness of the ceramics whose content of an alumina is 97% is too high, the measurement with Rockwell hardness is impossible. Then, it was Hv1400 when the Vickers hardness of this ceramics was measured. This Hv1400 is too high and the comparison with Rockwell hardness cannot do it.
[0005] Deformation or a wire expanded and contracted, and when the wire slot of a multi-slot roller was formed from nylon, the wire slot was compensating the precision error of a wire slot. However, since a wire slot does not deform when this wire slot is formed with the ceramics, only when a wire expands and contracts all the precision errors of a wire slot, it must compensate. Many [therefore, / when a wire slot is formed with the ceramics / farther than the case where the stress concerning a wire has a wire slot formed from nylon]
[0006] The multi-slot roller made from the ceramics of a wire saw must form a wire slot from the above-mentioned situation in a precision far higher than the multi-slot roller made of nylon.
[0007] The multi-slot roller made of nylon had processed the wire slot by cutting by the cutting tool using NC engine lathe. However, when processing the wire slot of the roller made from the ceramics, since a degree of hardness is very high, the ceramics becomes a grinding process by the diamond wheel using NC cylindrical grinder as mentioned above. Therefore, while the time amount which processing takes compared with the conventional example becomes remarkably long, processing costs also come to increase.
[0008] Moreover, grinding stones may have to be exchanged, as wear at the tip of a grinding stone is intense and is recessing of the one multi-slot roller made from the ceramics. However, if this grinding stone is exchanged, it will be difficult to double with the condition in front of exchange of the physical relationship of a wire slot and this

grinding stone precisely, a[illegible]t will become the error factor [illegible]the slot pitch of a result wire slot. Therefore, a wire slot cannot be precisely formed as a design, but it may become the cause of derailment and an open circuit.

[0009] Then, it is possible by making the wire depth of flute shallower than the conventional multi-slot roller made of nylon to solve said problem. However, if a wire slot is made shallow, it will become easy to generate derailment of a wire, and if a wire derails, the workpiece under cutting (work piece) will be spoiled.

[0010] Moreover, since the multi-slot roller made from the ceramics does not almost have deformation as mentioned above, high tension is used for a wire from the multi-slot roller made of nylon in many cases for the improvement in process tolerance, and the improvement in working speed, hanging on it. Furthermore, in order that this multi-slot roller may reduce the amount of shaving of a workpiece (work piece), and in order to cut much quantity at once, the wire of a thin path, for example, piano wire with a diameter of 0.1mm, is used. Therefore, if many loads are applied to a wire even when it is smaller than a design value on a wire, it will disconnect.

[0011] Furthermore, in recent years, diversification of a workpiece (work piece) progresses and the slot pitch of the wire slot demanded in connection with it is also crossed to a variety. When processing a workpiece into ultrathin especially, less than [slot pitch 0.2mm] is required, but if this slot pitch becomes small, naturally in proportion to it, slot Mayama's summit-of-the-mountain flight width will also become small. However, since the multi-slot roller made from the ceramics is a hard and brittle nature ingredient, if a summit-of-the-mountain flight width is made small, a chipping will generate it in slot Mayama at the time of wire recessing. Therefore, it becomes difficult to form slot Mayama as a design. When slot Mayama cannot form as a design, derailment of a wire and an open circuit occur or it has a bad influence also on the process tolerance of a workpiece (work piece).

[0012] This invention is making it a chipping not occur in view of the above-mentioned situation at the time of recessing. Other purposes aim at making it derailment and an open circuit not arise while they make the wire depth of flute shallower than that of the conventional example.

[Translation done.]

* NOTICES *

1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

MEANS

[Means for Solving the Problem] the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the content of an alumina for the slot formation part of; this multi-slot roller made from the ceramics with 90% or more of ceramics in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama on the front face -- it comes out. the multi-slot roller made from the ceramics of a wire saw with which this invention is characterized by forming the slot formation part of; this multi-slot roller made from the ceramics in a front face with the ceramics with a flexural strength of 3500kg/cm2 or more in the multi-slot roller made from the ceramics of the wire saw which has two or more wire slots and slot Mayama -- it is.
[0014] Two or more multi-slot rollers which this invention has two or more wire slots on a front face, and are arranged in parallel, The wire which is wound around the surroundings of two or more of these multi-slot rollers, and is guided by the wire slot, In the multi-slot roller made from the ceramics of a wire saw with which two, a preparation and this multi-slot roller, or more consist of multi-slot rollers made from the ceramics the wire depth of flute of; this multi-slot roller made from the ceramics It is 50-500 micrometers, the deflection of the radial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, and the deflection of the axial direction of the wire slot to the green sand core shaft of this multi-slot roller is 20 micrometers or less, the multi-slot roller made from the ceramics of the wire saw by which it is characterized -- it comes out. In this invention dispersion in the diameter of the wire slot of the one multi-slot roller made from the ceramics So that it may be 30 micrometers or less and accumulation of the error of the pitch of this wire slot may be 30 micrometers or less form or Moreover, you may form so that the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters a workpiece may be 60 micrometers or less and the

mutual cumulative error of the slot pitch which this wire slot faces may be 60 micrometers or less.
[0015]
[Embodiment of the Invention] When this invention person was narrow, for example, slot Mayama's summit-of-the-mountain flight width was set to 40 micrometers or less, he experimented in whether a chipping occurs or not, having thought that that a chipping occurs would not have a problem in the quality of the material, and changing the content of an alumina component. Consequently, when the content of an alumina became 90% or more and flexural strength became 3500kg/cm2 or more, it turned out that a chipping does not occur, for example even if set to 40 micrometers even if slot Mayama's summit-of-the-mountain flight width becomes narrow. Then, we decided that the content of an alumina adopts 90% or more of ceramics, or the ceramics with a flexural strength of 3500kg/cm2 or more as the quality of the material of the multi-slot roller made from the ceramics.
[0016] what a wire tends to derail or disconnect this invention person to in the case of the multi-slot roller made from the ceramics -- a wire slot -- the multi-slot roller made of nylon -- comparing -- deformation -- **** -- I thought that it was because it is few. That is, although the wire slot is compensating precision, such as a deflection of the wire slot of a multi-slot roller, with the multi-slot roller made of nylon when deformation or a wire develops, most adjustments by deformation of a wire slot cannot be found, and are compensating all precision with the multi-slot roller made from the ceramics only with the wire.
[0017] Although what is necessary is just to form a wire slot precisely so that it may be without error to a design value in order to prevent derailment of a wire, and an open circuit, it is very difficult to form such. Then, when this invention person pursued the cause of derailment and an open circuit, it turned out that the main cause is in the deflection (henceforth the deflection of the axial direction) of the axial direction of the wire slot to the green sand core shaft of a multi-slot roller, and the deflection (henceforth the deflection of a radial direction) of the radial direction of the wire slot to the green sand core shaft of a multi-slot roller.
[0018] Then, even if these deflections arose, when it asked for the range which is not derailed and disconnected, i.e., the tolerance of a deflection, 20 micrometers or less of deflections of 20 micrometers or less and a radial direction came out [the wire depth of flute / the deflection of the axial direction] in the wire slot of the 50-500-micrometer multi-slot roller made from the ceramics, and a certain thing was understood.
[0019] Furthermore, when the following conditions were fulfilled, it turned out that it is more desirable.
(1) The path of the bay which connects the point that the path and wire of the path of the

wire slot of an one multi-slot roller, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and ********** should be 30 micrometers or less.
(2) The path of the bay which connects the point that the path and wire of the diameter of the wire slot of each of this **** roller of the two multi-slot roller made from the ceramics which counters a workpiece, i.e., the groove bottom of a wire slot, contact the both-sides wall of a wire slot, and the sum total of ********** should be 60 micrometers or less.
[0020] (3) The slot pitch cumulative error of the wire slot of an one multi-slot roller should be 30 micrometers or less.
(4) The cumulative error of the slot pitch of the wire slot where the two multi-slot roller made from the ceramics which counters a workpiece faces should be 60 micrometers or less. Then, it decided to adopt the wire slot in the above tolerance as processing conditions.
[0021] In addition, although the wire slot of the multi-slot roller made from the ceramics must be formed so that a wire can be attached, **** selection of the configuration, magnitude, the number, etc. is made if needed. For example, it is made a configuration to which a wire contacts the groove bottom of a wire slot, and is formed in a configuration to which a wire contacts the both-sides wall of a wire slot.
[0022] Moreover, 90% or more of purity, i.e., the content of an alumina, is used for 90% or more of ceramics, a zirconia, silicon carbide, silicon nitride, etc. as ceramics which forms a multi-slot roller.
[0023]
[Example 1] Drawing 1 - drawing 6 explain the first example of this invention. the multi-slot roller 1 made from the ceramics of a wire saw is formed in the bell shape with the ceramics, the outer diameter D comes out 40mm, and the bore of 1d comes out out of 20mm and die length Ln 100mm. As this ceramics, the ceramics whose content of an alumina is 90 97%% or more, for example, purity, is used.
[0024] The reinforcement member 5 is formed in the centrum 2 of this multi-slot roller 1. This reinforcement member 5 is the disk configuration of the shape of the said heart formed in this multi-slot roller 1 and one. 5t in thickness of the reinforcement member 5 of this disk configuration -- the same thickness as thickness 1t=10mm of the multi-slot roller 1 -- it comes out, it is, and although both ratio of wall thickness to outside diameter 1t/5t is 1, this ratio of wall thickness to outside diameter 1t/5t is chosen in consideration of the rigidity of a multi-slot roller etc.
[0025] Although one reinforcement member 5 of a disk configuration is formed, when **** selection also of this arrangement number is made in consideration of the die length Ln of this multi-slot roller 1 etc., for example, the reinforcement member 5 of three disk configurations is arranged in the direction of green sand core shaft C at equal intervals,

the reinforcement member may be omitted conversely.
[0026] In the reinforcement member 5 of a disk configuration, five holes 6 for lightweight-izing are established, and lightweight-ization of the reinforcement member 5 is attained by this hole 6 for lightweight-izing to it. In consideration of the rigidity of the multi-slot roller 1 demanded, **** selection of the location of this hole 6 for lightweight-izing, the number, the configuration, etc. is made, for example, the hole 6 for lightweight-izing has not penetrated, or the eight polygon-like holes 6 for lightweight-izing are adopted.
[0027] Spacing is set in surface 1a of this multi-slot roller, and two or more wire slots 10 are formed in the direction of green sand core shaft C at it. This wire slot 10 is precisely processed based on engineering drawing with NC cylindrical grinder which is not illustrated. For example, the wire channel depth 10d=0.12mm, the slot include angle of theta= 60 degrees, the slot pitch of P= 0.24mm, a flute width = it is formed in 0.2mm, slot Mayama's summit-of-the-mountain flight width of W= 0.04mm, and 296 slots.
[0028] The metal supporter material 30 formed disc-like is formed in both-ends 1e of this multi-slot roller 1. A shank 31 is arranged in the center section of outside 30a of this metal supporter material 30, and the fitting section 33 is formed in the periphery section of the inside 30b. Although fitting of this fitting section 33 is carried out to edge 1e of the multi-slot roller 1, these both sections 33 and 1e are pasted up with the adhesives 35, such as an epoxy resin.
[0029] Since these Ryobe's 33 and 1e junction die length L33 is very shorter than the die length Ln of the multi-slot roller 1, a temperature change arises by operating the equipment of a wire saw, and even if both expand, contract and displace, Ryobe's junction condition is maintained. In addition, as for this metal supporter material 30, it is desirable to be formed in a disk configuration with the ingredient of coefficient of thermal expansion [**** / the same as that of the coefficient of thermal expansion of the ceramics or], although iron, steel, etc. are generally used, for example, titanium, a titanium alloy, etc. are used as this ingredient.
[0030] Next, actuation of a wire saw is explained. The multi-slot roller attachment part of the wire saw which is not illustrated is equipped with the shank 31 of the multi-slot roller 1. The wire 50 of one 0.12mm diameter is twisted around the wire slot 10 which faces, surrounding two or more of these multi-slot rollers 1 with which it was equipped, and much wire train 50A is formed. at this time, dispersion with a diameter [the diameter of 10n of the wire slot of an one multi-slot roller], i.e., the diameter of wire groove bottom 10R, and a diameter [of bay 10W which connect the contacting point that 10f of side attachment walls and the wire of both sides of a wire slot contact] of 10m is 30 micrometers or less, and 30 micrometers or less of cumulative errors of the slot pitch P of this wire slot come out.

[0031] Moreover, the sum total of dispersion in the diameter of the wire slot of each multi-slot roller of the two multi-slot roller made from the ceramics which counters the workpiece currently used within 1 equipment, Namely, the diameter of 10n of wire groove bottom 10R of each multi-slot roller made from the ceramics, The sum total of dispersion with a diameter [of bay 10W which connect the contacting point that 10f of side attachment walls and the wire of both sides of a wire slot contact] of 10m is 60 micrometers or less, and the accumulation of the mutual error of the slot pitch P which the multi-slot roller made from the ceramics which faces faces is 60 micrometers or less.
[0032] Round trip or one direction rectilinear motion of the wire train 50A is carried out like an arrow head A50 by reversal-going or one direction rotating a multi-slot roller. the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of the multi-slot roller 1 made from the ceramics at this time is 20 micrometers or less, and 20 micrometers or less of deflections of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 made from the ceramics come out of it.
[0033] While pressing Workpiece (work piece) BW against this wire 50, abrasives are cut from the regurgitation nozzle which is not illustrated, making an abrasive material intervene between discharge and both.
[0034] Although inertial force occurs with rotation of this multi-slot roller 1 made from the ceramics, since this multi-slot roller 1 is very lightweight compared with the conventional example, it will become very small [that inertial force].
[0035] Moreover, although a temperature change may arise at the time of operation of a wire saw and both this multi-slot roller 1 made from the ceramics and the metal supporter material 30 may expand and contract, if both 1 and 30 are in abbreviation etc. by carrying out and coefficient of thermal expansion is made from them, since it expands and contracts in coincidence at an abbreviation same rate and the exfoliation like jointing etc. will not occur, it is desirable.
[0036] Although the deflection of a wire slot occurs at the time of operation of the above-mentioned wire saw, the deflection of radial direction AR of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less, and the deflection of the axial direction AX of the wire slot 10 to the green sand core shaft C of this multi-slot roller 1 is 20 micrometers or less.
[0037] As a result of performing cutting processing of the silicon whose diameter is 8 inches in the wire saw which used the above-mentioned multi-slot roller made from the ceramics, derailment of a wire, an open circuit, etc. did not occur, and exfoliation of the ceramic section and metal supporter material etc. was not seen, but the dimensional accuracy of the wafer which is a workpiece was able to maintain 5 micrometers or more, and was able to be processed.
[0038] The tolerance of the deflection of the wire slot of radial direction AR to the green

sand core shaft C of the multi-slot roller 1 made from the ceramics in this example is called for also by count. The tolerance of this deflection shows the limitation of the deflection which derailment generates.
[0039] Next, said tolerance is calculated by drawing 6 which is the derailment nomogram of this example. Although various causes are put together and derailment of the wire of a wire saw is generated, the progress of the derailment is as follows.
(1) In order that the wire which has run from the next wire slot may enter aslant to a wire slot, a wire 50 contacts 10f of side attachment walls of this wire slot like [near B of drawing 6].
[0040] (2) This wire receives rotation of the multi-slot roller 1 made from the ceramics, and the force to the direction of a periphery of 10f of side attachment walls.
(3) The green sand core shaft C spacing L between the two multi-slot rollers which counters becomes short by the deflection of radial direction AR of the wire slot of the multi-slot roller made from the ceramics, and a wire 50 loosens and derails.
[0041] The following relational expression is called for from drawing 6 which shows the time of this derailment.
Y+z=L+l+delta x (1)
costheta=r/(r+t) (2)
l=2pi rxtheta / 360 (3)
r2+z2=(r+t)2 (4)
(L-delta x) 2+t2=y2 (5)
[0042] In the above-mentioned formula, the amount of deflections of the wire slot of a precise distance, the die length of l:radii, an r:multi-slot roller, and the radius of the contact part of a wire, the wire migration length at the time of t:derailment initiation and a deltax:multi-slot roller is shown theoretically between L:multi-slot rollers, respectively.
[0043] The above-mentioned formula (1) From - (5), the deflection of the wire slot of the multi-slot roller which derailment generates is searched for. Next, the example of count is shown.
The example 1 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment generates.
L= 100 Unit [mm]
r= 20t=0.4[0044]
(2) Formula COStheta=20/(20+0.4) =0.98039 Theta=COS - 10.98039= 11.365 degrees
(3) types l=2pix20x11.365 / 360= 3.9671 (4) types Z=root (r+t) (2-r2)
= root (20+0.4) (2-202)
= 4.0200 [0045] From (1) and (5) types (L-delta x) 2+t2=(L+l+delta x-z) 2 therefore (100-deltax) 2+0.42 = (100+3.967-4.0200+deltax) [2] 10000-200delta x+delta x2 +0.16 =9989.4028+199.894deltax+2deltax2 therefore deltax2+399.894deltax-10.757=0

deltax=26.9[mum] [0046] The example 2 of count: The conditions for calculating the amount delta x of deflections of the wire slot of the multi-slot roller which derailment generates.
L= 100 Unit [mm]
r= It calculates like the example 1 of 30t=0.4 count, and is deltax=21.7[mum].
[0047] Although the amount delta x of deflections of the wire slot of the multi-slot roller made from the ceramics was calculated by the above-mentioned example of count, as for the deflection of radial direction AR of a wire slot to the green sand core shaft C of the multi-slot roller made from the ceramics, it is desirable to manufacture so that it may be set to 20 micrometers or less from said examples 1 and 2 of count.
[0048]
[Example 2] Drawing 7 explains the 2nd example of this invention. The difference of this example and 1st example is as follows. the cross-section configuration of the wire slot 10 -- setting -- slot include-angle theta1=90 degree of a base, and the slot include angle theta of a side attachment wall -- they are 2= 10 degrees, the flute width of B= 0.3mm, slot Mayama's summit-of-the-mountain flight width of W= 0.1mm, channel depth 10d=0.3mm, and slot pitch =0.4mm.
[0049]
[Example 3] Drawing 8 explains the 3rd example of this invention. The next experiment was conducted in order to know the relation between the alumina content (purity %) of the multi-slot roller made from the ceramics or flexural strength, and the summit-of-the-mountain flight width of slot Mayama whom a chipping does not generate at the time of processing. As shown in drawing 8 , the maximum summit-of-the-mountain flight width W as which 1 micrometer of wire slots 10 of the same configuration is narrowed from each pitch 0.4mm on the multi-slot roller 1 made from the ceramics with which alumina contents differ, and generating of a chipping is regarded in this each **** roller was investigated. In addition, the processing conditions are as follows.
[0050] processing machine: -- NC cylindrical-grinder grinding stone: -- the result of a diamond wheel, the grain-size #400 processing work-piece (alumina material):diameter of 65mm, the die-length rotational frequency [of 100mm] 200rpm processing quirk-like:slot include angle of theta= 60 degrees, and a channel depth 10d= 0.15mm experiment is shown in Table 1 and drawing 9 , and drawing 10 .
[0051]
[Table 1]

アルミナ純度（%）	チッピング発生最大山幅（μm） 実験1	実験2	実験3	平均	曲げ強度（kg／cm²）
75	99	93	84	92.0	2300
88	82	72	73	75.6	2700
90	31	34	31	32.0	3500
97	44	45	32	40.3	4100
99.5	18	13	19	16.7	3600

[0052] Drawing 9 is drawing showing the relation between an alumina content (axis-of-abscissa %), i.e., alumina purity, and a chipping generating summit-of-the-mountain flight width (axis-of-ordinate mum). In this drawing, as for the 2nd experimental result and the trigonum mark, the 1st experimental result and the square mark show an average for a round mark, as for the 3rd experimental result and x mark.
[0053] Drawing 10 is drawing showing the relation between alumina purity (axis-of-abscissa %), a chipping generating summit-of-the-mountain flight width (left axis-of-ordinate mum), and flexural strength (right axis-of-ordinate kg/cm2). In this drawing, the square mark shows a summit-of-the-mountain flight width, and a round mark shows flexural strength.
[0054] Table 1 and drawing 9 , and drawing 10 showed that 75% of alumina contents, 88% of thing or the flexural strength of 2300kg/cm2, and the summit-of-the-mountain flight width of a 2700kg/cm2 thing had the large quality of the material 2 or 3 or more times compared with the summit-of-the-mountain flight width of a thing (90% of alumina purity, 92%, 97%, and 99.5% of thing or the flexural strength of 3500kg/cm2, 4100kg/cm2, and 3600kg/cm2). That is, it turned out that a chipping does not occur even if it will make extremely narrow the summit-of-the-mountain flight width W, if the content of an alumina becomes 90% or more or the flexural strength of 3500kg/cm2 or more.
[0055]
[Example 4] The 4th example of this invention is explained. The chipping was not generated, although the diamond wheel was used for the multi-slot roller with a diameter of 60mm which consists of an alumina of 97% of purity made from the ceramics and the wire slot with a slot pitch [of P= 0.3mm] and a summit-of-the-mountain flight width [of

slot Mayama] of W= 50 micrometers was processed into it. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of Xtal was performed, cutting with a as precise thickness precision as 5 micrometers or more was performed. Although the wire slot was ground faint [every] with the abrasive grain adhering to a wire and was worn out, it was able to maintain the above-mentioned precision over the long time of 300 hours, and was able to perform cutting processing.
[0056]
[Example 5] The 5th example of this invention is explained. Although the diamond wheel was used for the multi-slot roller made from the ceramics of the same specification as the above which consists of an alumina of 97% of purity and the wire slot with a wire slot pitch [of P= 0.25mm] and a summit-of-the-mountain flight width [of slot Mayama] of W= 40 micrometers was processed into it, the chipping was not generated like the example 4. When the wire saw was equipped with this multi-slot roller and ultra-thin cutting processing of the magnetic substance was performed, it came out to maintain 5 micrometers or more like the above, and the thickness precision of a work piece came.
[0057]
[Example 6] Drawing 11 explains the 6th example of this invention. A roller does not necessarily need to form all with said ceramics, and if the slot formation part is formed with said ceramics, it is sufficient for it. The example is as follows.
(1) As shown in drawing 11 (A), form the cylindrical periphery section 81 made from said ceramics with which the wire slot 10 stuck to the metal pipe 80. The stop member 83 for an applied part 82 being formed in the both ends of this metallic pipe 80, and fixing the periphery section 81 to an end is formed.
[0058] (2) As shown in drawing 11 (B), form the cylindrical periphery section 91 made from said ceramics with which the wire slot 10 stuck to the metal pipe 90. The **-like ring part 92 is formed, the reinforcement disk 95 with which the hole 94 opened is formed in a centrum 93, and the lid 96 which fixes this periphery section 91 is fixed to other end 90b by end 90a.
[0059]
[Example 7] Drawing 12 explains the 7th example of this invention. A slot formation part is formed with said ceramics, and this example as well as said 6th example is a case.
(3) As shown in drawing 12 (A), form the cylindrical periphery section 101 made from said ceramics with which the wire slot 10 stuck to the metal pipe 100. The bearing shank 105 is formed in end 2100a of this metal pipe 100, and the truncated-cone-like bearing 106 is formed in other end 100b. The cylindrical crevice 107 is formed in the periphery of this pipe 100, and said cylindrical periphery section 101 is being attached and fixed to this crevice 107.
[0060] (4) As shown in drawing 12 (B), form the cylindrical periphery section 111 made

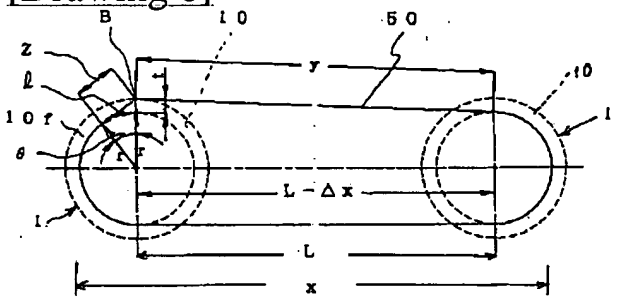
from said ceramics with w[illegible]n the wire slot 10 stuck to the [illegible]tal pipe 110. The truncated-cone-like bearings 115 and 116 are formed in the both ends of this metal pipe 110. The cylindrical crevice 117 is formed in the periphery of this pipe 110, and said cylindrical periphery section 111 is attached and fixed to it by this crevice 117.
[0061]
[Example 8] Drawing 13 explains the 7th example of this invention. In said example, although the slot formation part was formed with said ceramics, this whole multi-slot roller made from the ceramics can also be formed with said ceramics. The example is as follows.
(1) As shown in drawing 13 (A), form the bell shape roller 120 with said ceramics, and form the wire slot 10 in the periphery section 121 of this roller. Since this roller 120 does not have a reinforcement member into a centrum 123 unlike said 1st example, in order to maintain reinforcement, that thickness Rt is thicker than that of the 1st example, for example, is formed in twice as many thickness as this.
[0062] (2) As shown in drawing 13 (B), form the bell shape roller 130 with said ceramics, and form the wire slot 10 in the periphery section 131 of this roller 130. The bearing shank 135 is formed in the end of this roller 130, and the truncated-cone-like bearing 136 is formed in the other end. In addition, the bearing shank 135 is covered with the metal 138, in order to improve concordance with bearing.

[Translation done.]

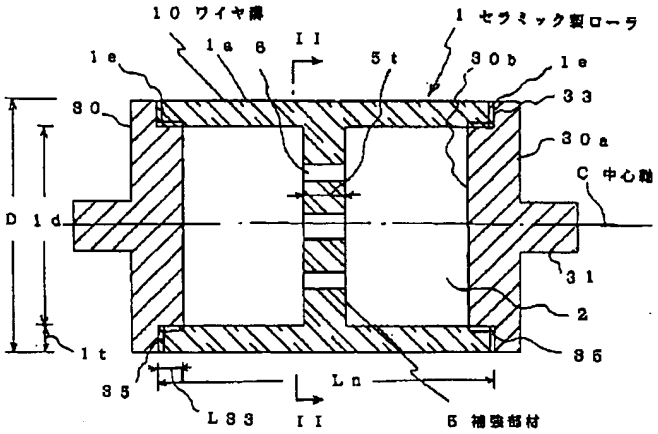
* NOTICES *

DRAWINGS

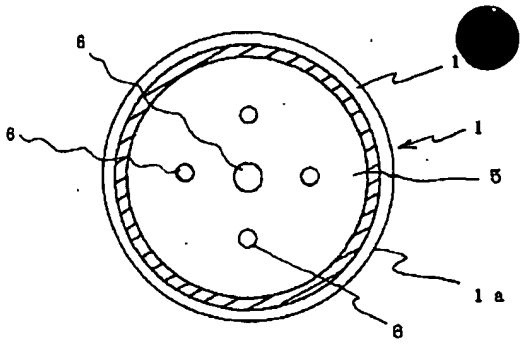
[Drawing 6]



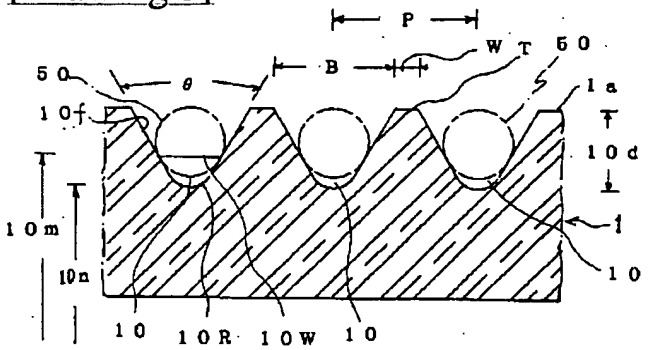
[Drawing 1]



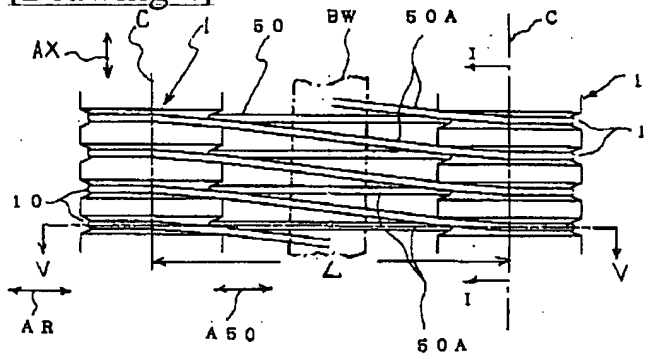
[Drawing 2]



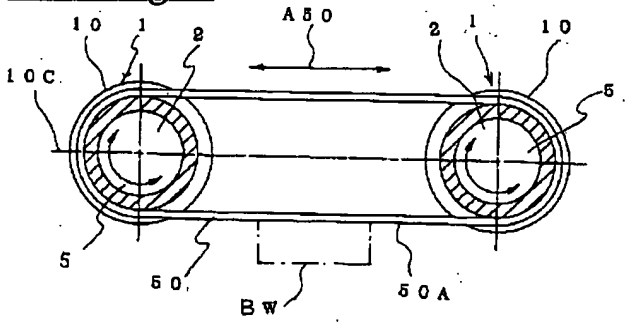
[Drawing 3]



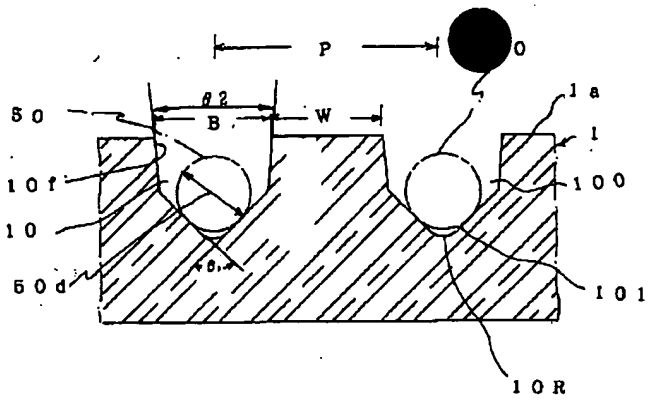
[Drawing 4]



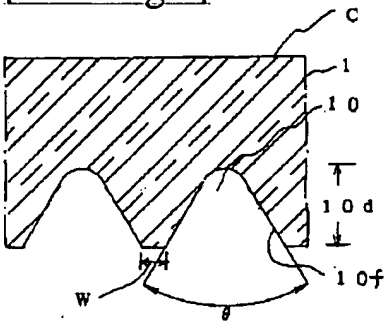
[Drawing 5]



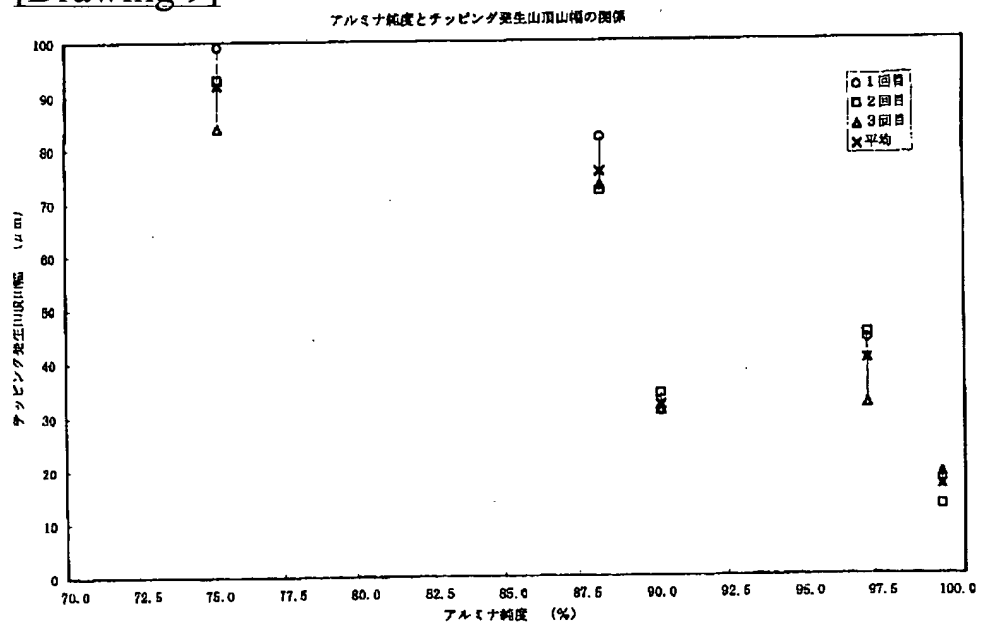
[Drawing 7]



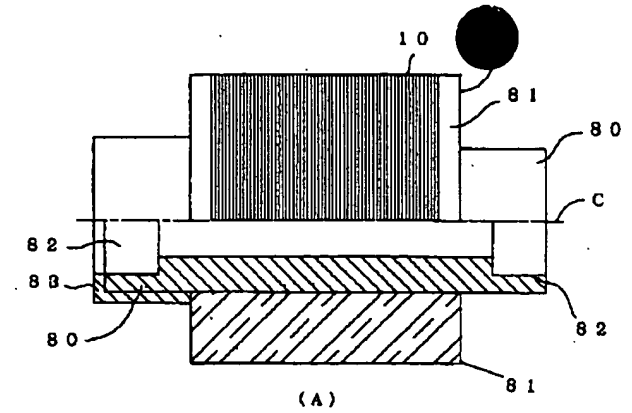
[Drawing 8]

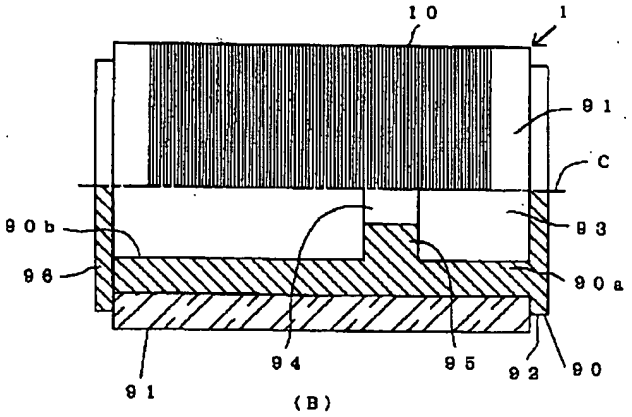


[Drawing 9]

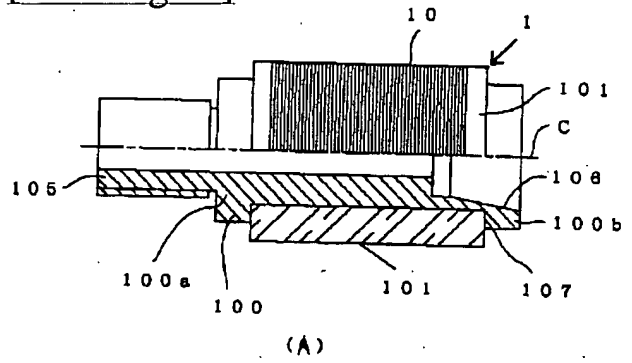


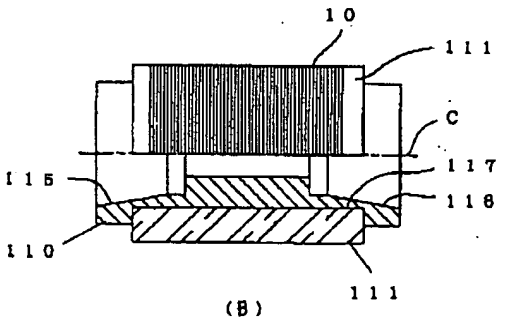
[Drawing 11]



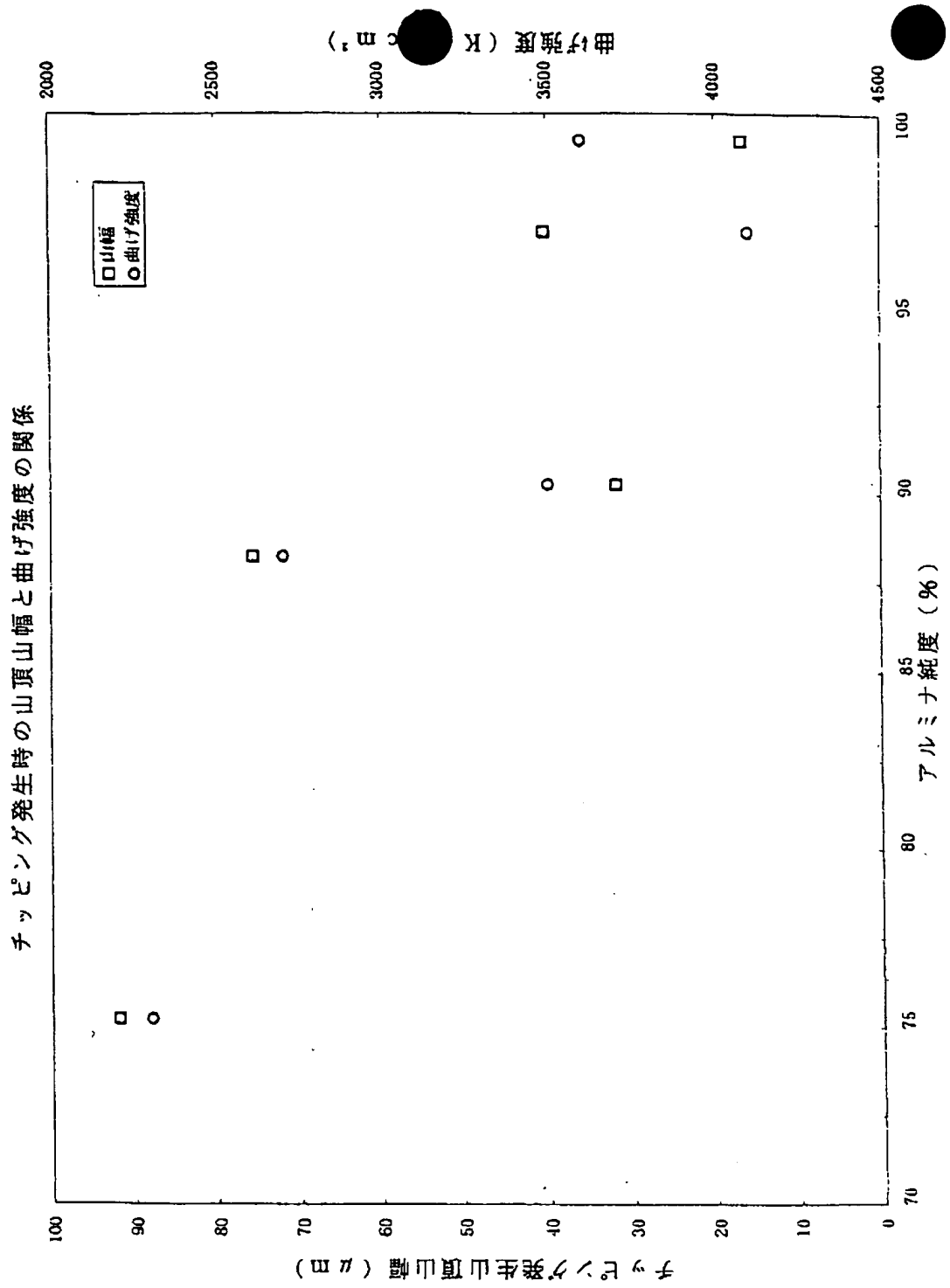


[Drawing 12]

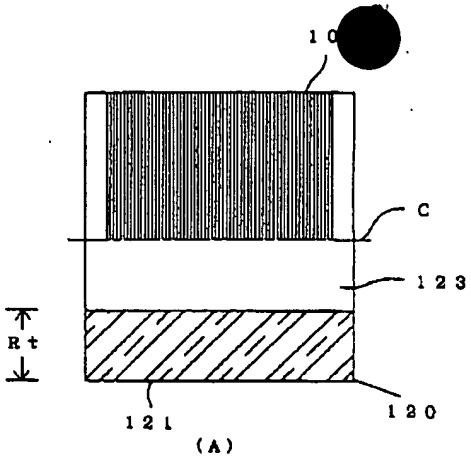




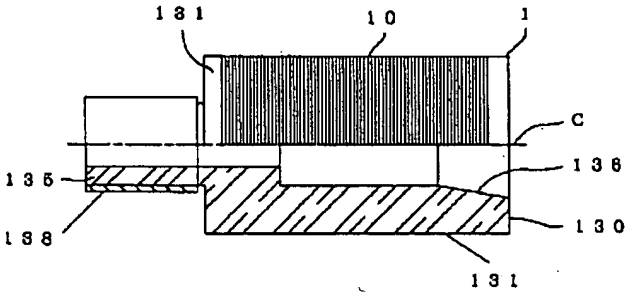
[Drawing 10]


チッピング発生時の山頂山幅と曲げ強度の関係
□山幅
○曲げ強度
チッピング発生山頂山幅（μm）
曲げ強度（K
アルミナ純度（%）
0
10
20
30
40
50
60
70
80
90
100
70
75
80
85
90
95
100
2000
2500
3000
3500
4000
4500

[Drawing 13]



(A)



(B)

[Translation done.]